woGIS semantics

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# *Discovering Spatio-temporal Nature of Phenomena from Linked Open Data Generated from SDI Spatial Resources, Using Formal Ontologies*

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## *Background and context of problem*

### Spatial management tasks and problems

- The purpose of planning is: to solve the conflict between civilization development and environmental protection;
- It requires continuous diagnosing of environment immunity against settlement and economic pressures.
- Planning need to be interdisciplinary and continuous in time.
- It must take into account the dynamics of the processes affecting the integrity of the natural system.

## *Background and context of problem*

**Via media – balanced development and protection**

- *Sustainable development is development that meets the needs of the present without compromising the ability of future generations to meet their own needs. It contains within it two key concepts:*
  - *The concept of "needs", in particular the essential needs of the world`s poor, to which overriding priority should be given; and*
  - *The idea of limitations imposed by the state of technology and social organization*.

  (Ralf K. Stappen, 2006*)*

# Discovering Spatio-temporal Nature of Phenomena from Linked Open Data Generated from SDI Spatial Resources, Using Formal Ontologies

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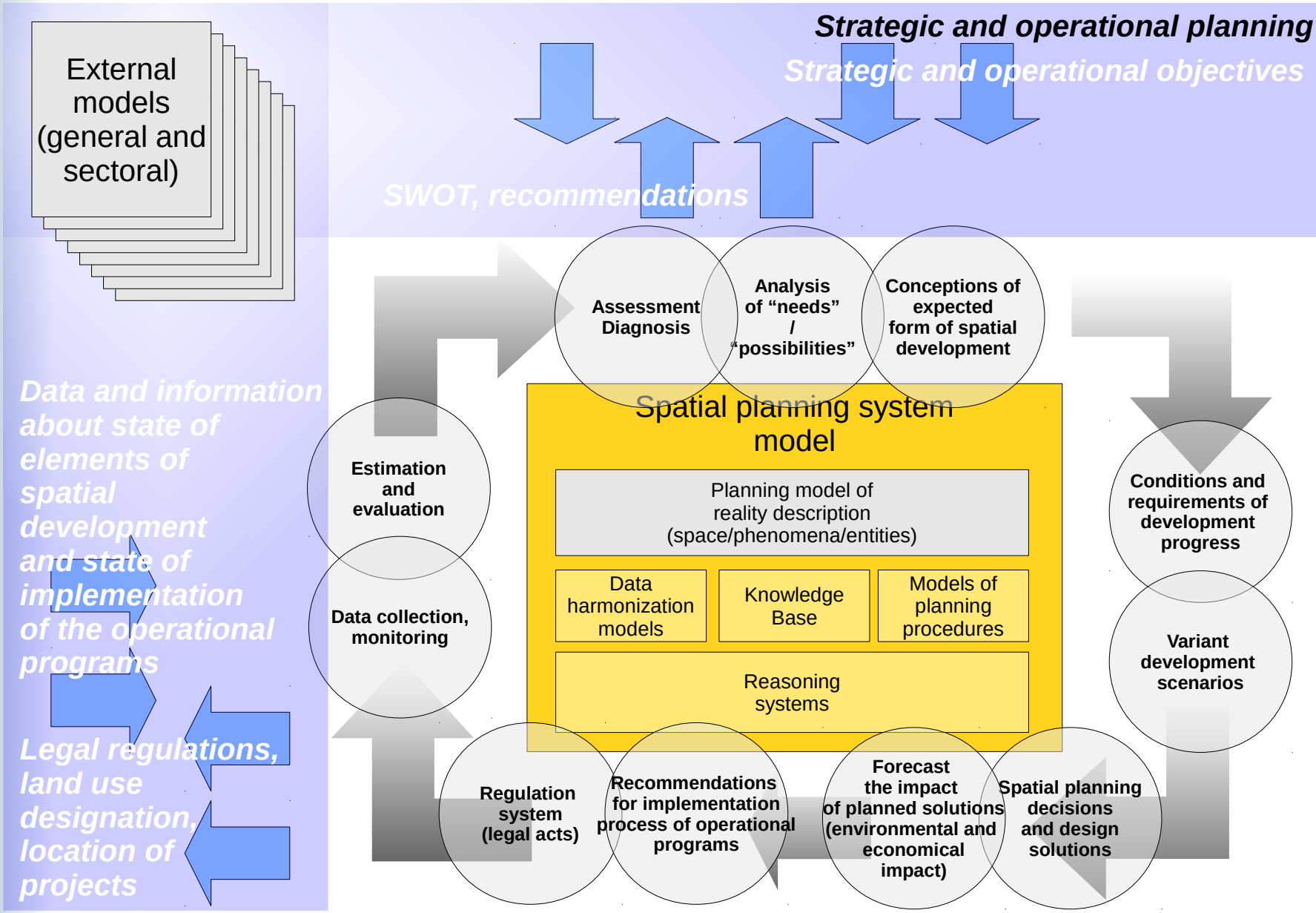

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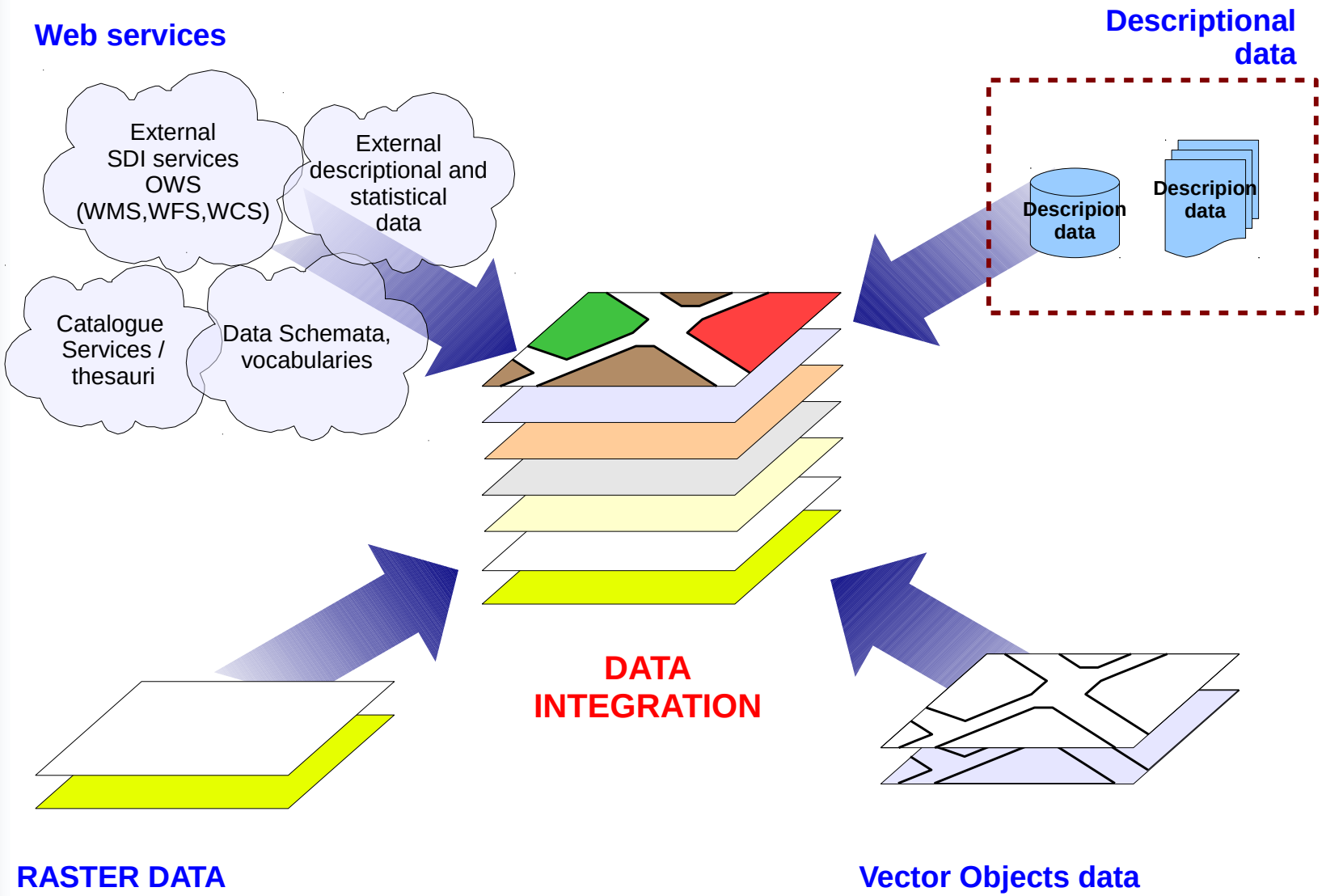

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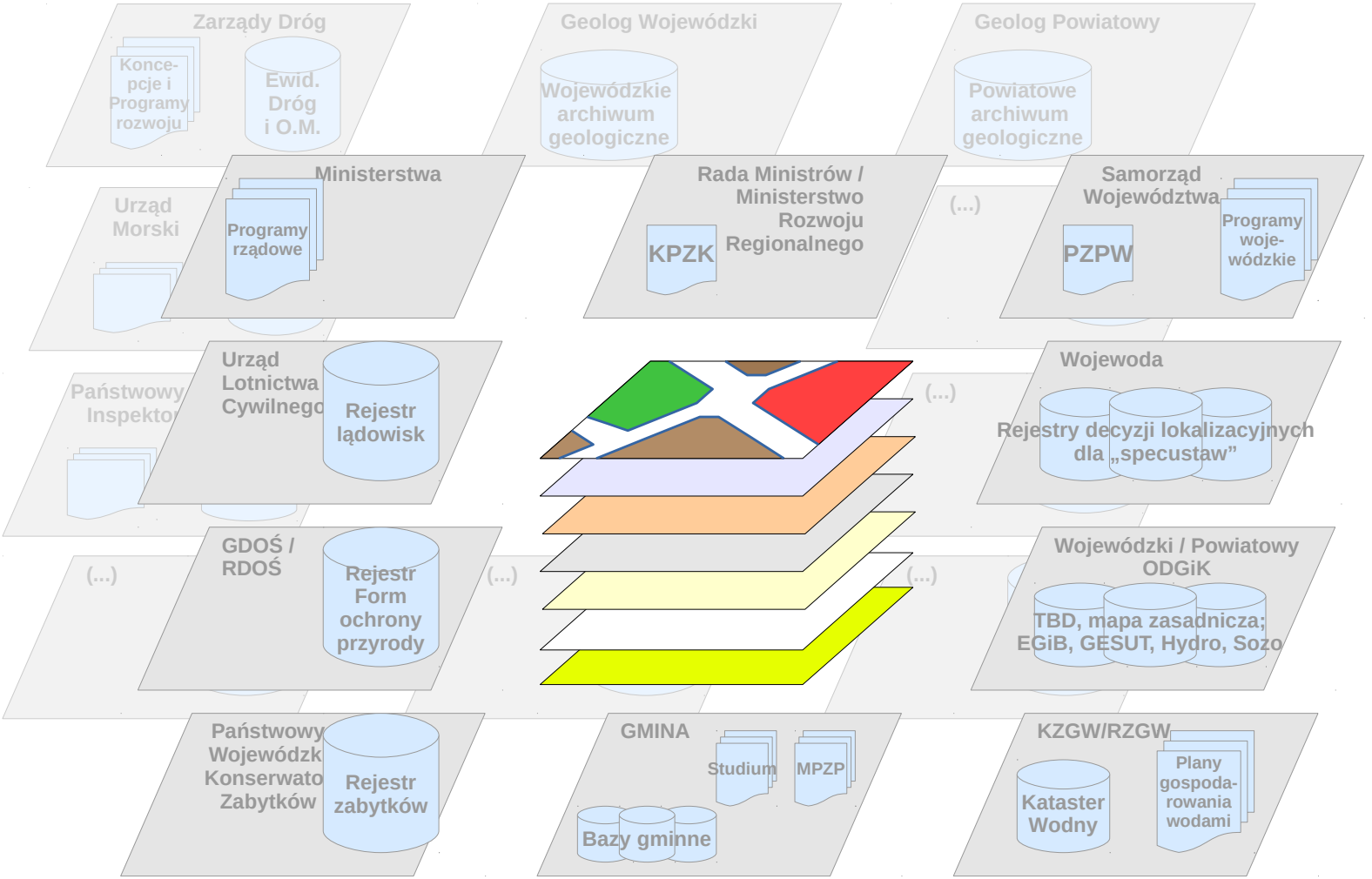

## *History of changes: snapshots, time slices*

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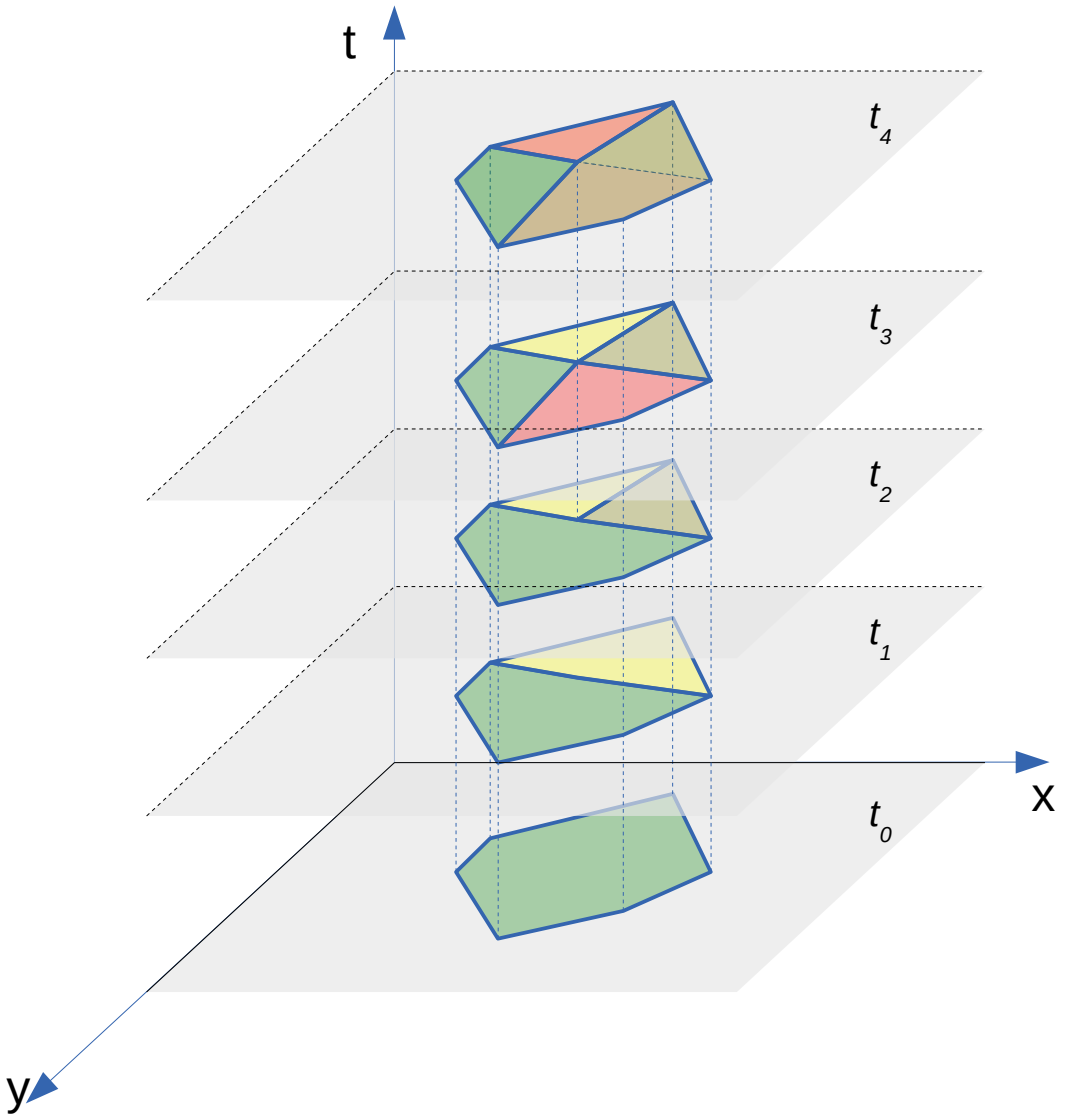
## *Representation of changes in form of history (series of snapshots)*

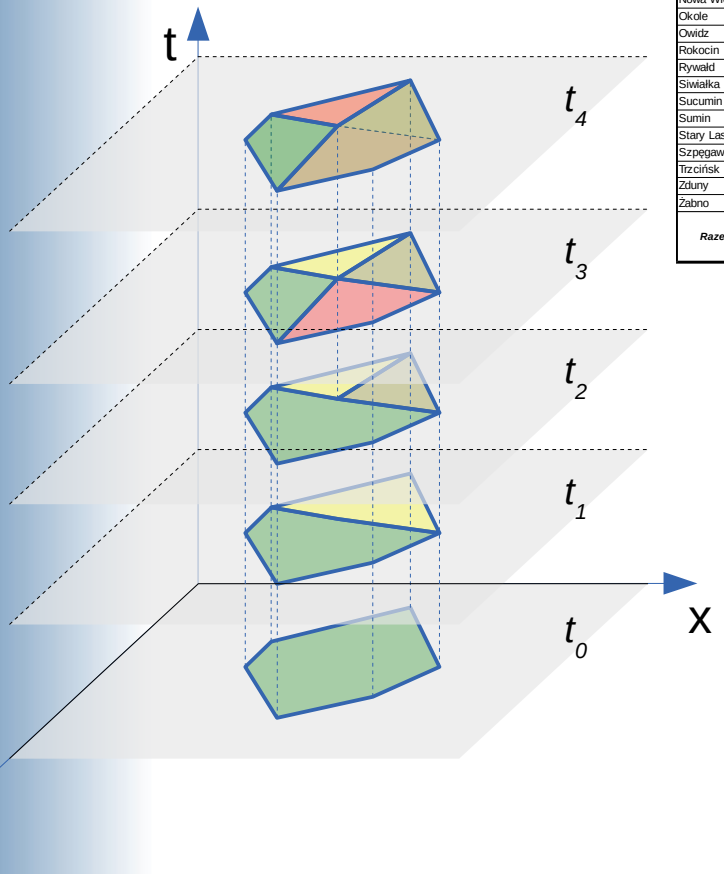


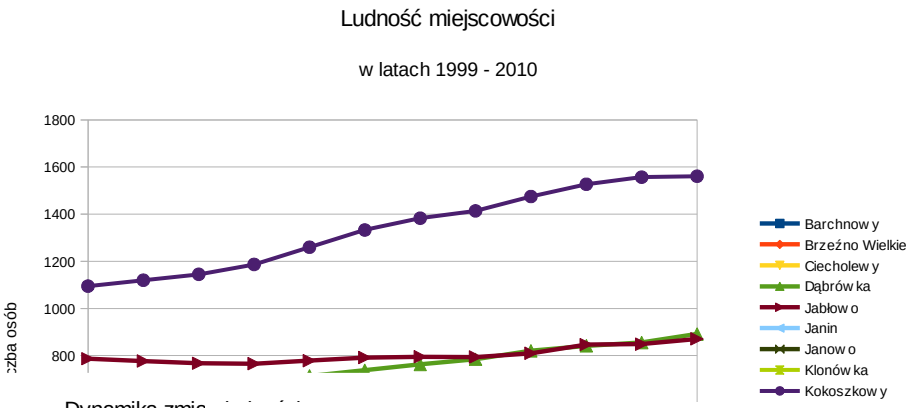
# Discovering Spatio-temporal Nature of Phenomena from Linked Open Data Generated from SDI Spatial Resources, Using Formal Ontologies

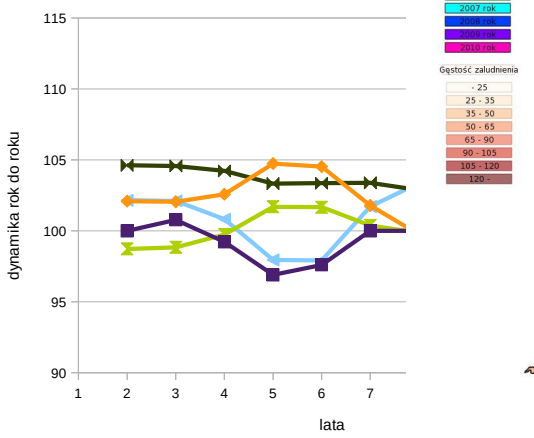
woGIS semantics

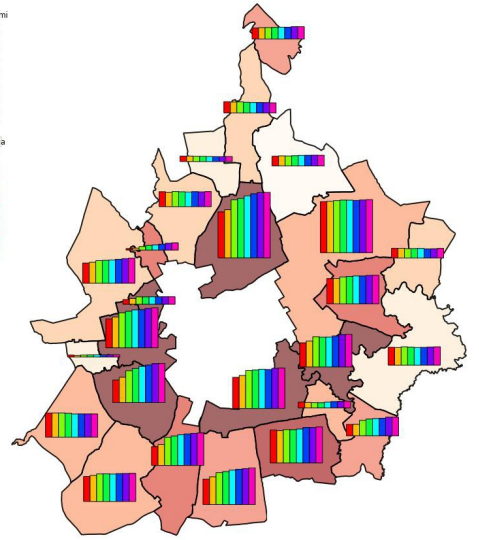
## *Different ways of presenting the changes of spatial phenomena*

| Nazwa wsi | Stan ludności w latach / Population recorded in each year | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | 31.12.2000 | 31.12.2001 | 31.12.2002 | 31.12.2003 | 31.12.2004 | 31.12.2005 | 31.12.2006 | 31.12.2007 | 31.12.2008 | 31.12.2009 | 31.12.2010 |
| Barchnowy | 133 | 129 | 126 | 125 | 125 | 125 | 124 | 137 | 151 | 158 | 164 |
| Brzeźno Wielkie | 229 | 231 | 230 | 226 | 222 | 222 | 224 | 230 | 217 | 220 | 236 |
| Ciecholewy | 237 | 242 | 244 | 239 | 234 | 238 | 246 | 254 | 257 | 259 | 255 |
| Dąbrówka | 634 | 663 | 691 | 714 | 738 | 763 | 785 | 821 | 842 | 856 | 892 |
| Jabłowo | 777 | 768 | 766 | 779 | 792 | 795 | 794 | 810 | 847 | 849 | 871 |
| Janin | 129 | 130 | 129 | 125 | 122 | 122 | 122 | 119 | 116 | 116 | 122 |
| Janowo | 342 | 349 | 358 | 375 | 392 | 399 | 398 | 407 | 407 | 430 | 448 |
| Klonówka | 422 | 420 | 420 | 429 | 439 | 437 | 427 | 420 | 423 | 430 | 446 |
| Kokoszkowy | 1120 | | | | | | | | | | |
| Kolincz | 596 | | | | | | | | | | |
| Koteze | 474 | | | | | | | | | | |
| Krąg | 490 | | | | | | | | | | |
| Linowiec | 347 | | | | | | | | | | |
| Lipinki Szlacheckie | 272 | | | | | | | | | | |
| Nowa Wieś Rzeczna | 710 | | | | | | | | | | |
| Okole | 41 | | | | | | | | | | |
| Owidz | 423 | | | | | | | | | | |
| Rokocin | 571 | | | | | | | | | | |
| Rywałd | 606 | | | | | | | | | | |
| Siwiałka | 267 | | | | | | | | | | |
| Sucumin | 575 | | | | | | | | | | |
| Sumin | 607 | | | | | | | | | | |
| Stary Las | 42 | | | | | | | | | | |
| Szpęgawsk | 608 | | | | | | | | | | |
| Trzcińsk | 265 | | | | | | | | | | |
| Zduny | 612 | | | | | | | | | | |
| Żabno | 123 | | | | | | | | | | |
| Razem Gmina | 11 652 | 11 | | | | | | | | | |



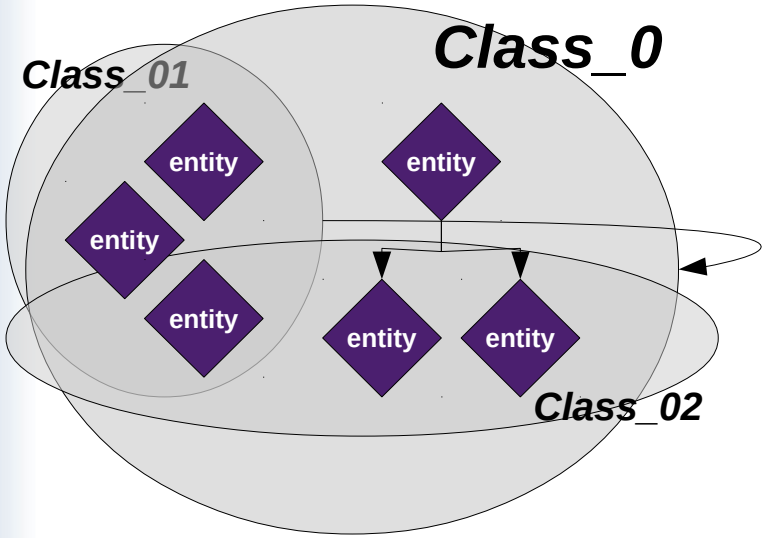



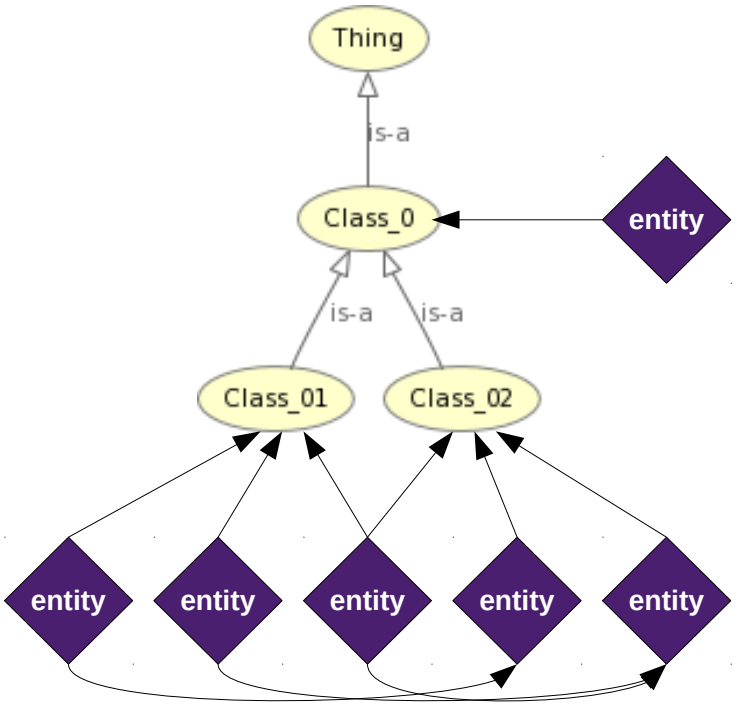
# *Ontology - conceptualization based on relationships and classification (Description Logic - DL)*

## Semantic representation of entities

**Class, as generalization of set – set distinguished by properties of entities**




**Semantic description of beings – assertions of items representing entities to defined types (classes) and relatioships between them**



## *Triple: the foundation of RDF structure for recording DL ontologies, using OWL*

**Structure in particular used, when we record ontology in OWL**


| predic_z | |
|---|---|
| ***Subject*** | ***Object*** |
| res_x | res_y |
| res_... | res_... |
| res_... | res_... |
| res_... | res_... |

## *Components of ontology in computer sciences*

**Vocabulary and assertions**

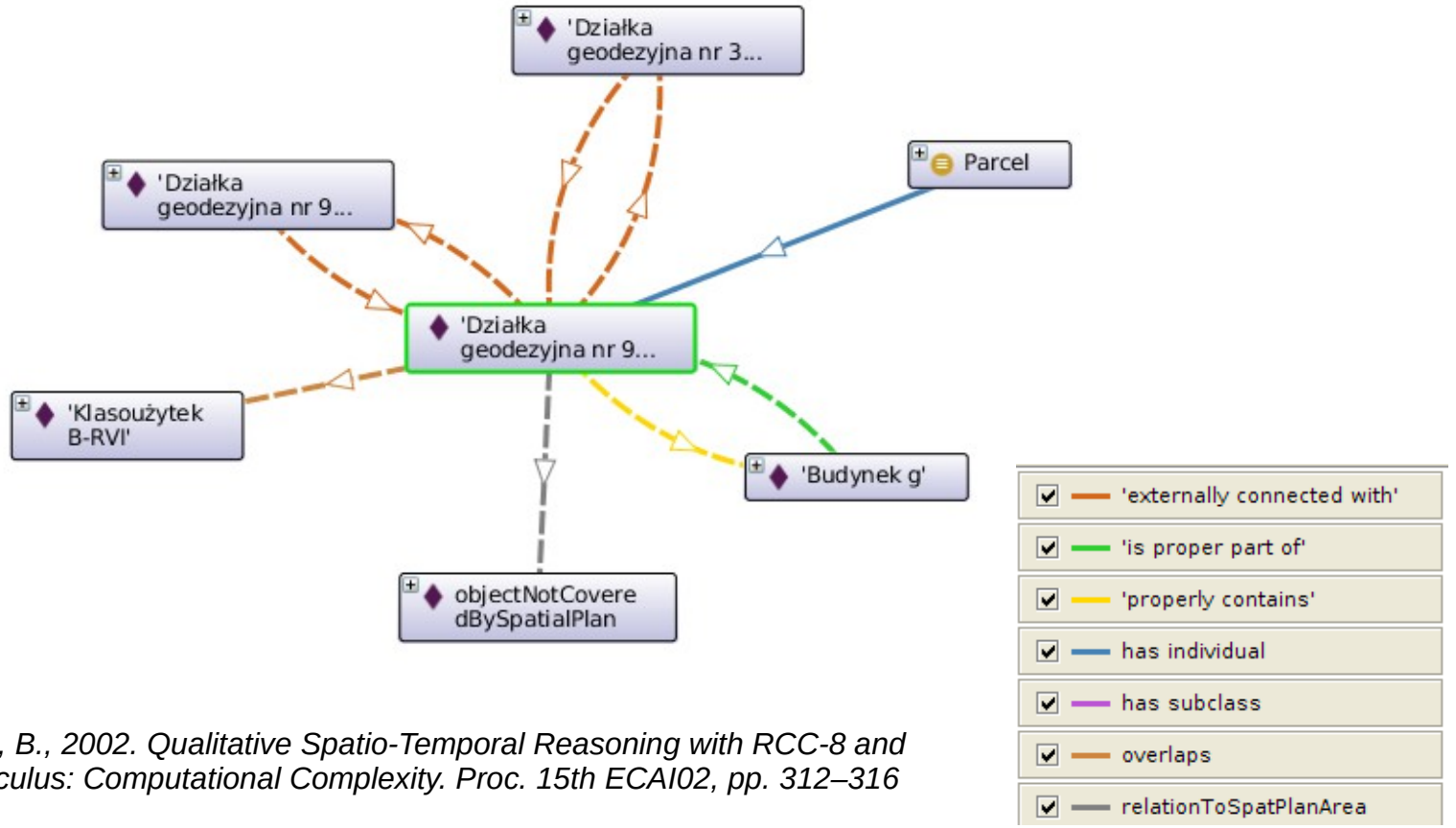
- TBox – terminological component
  - defines class hierarchy with, optional, classification criteria,
  - defines properties hierarchy between objects represented by classes (relationships and qualities), as well as domains and ranges of properties

(sometimes are distinguished TBox and Rbox – terminological and relational components)

- ABox – assertional component: reflecting concrete structure of described domain of discourse – data items represent their real designates, conceptualized by assertions to their types (classes) with revelation of actual relationships between them.

# *Description of land lot, by relationships to other objects*

## Assertions of type and relationships




*Gerevini, A., Nebel, B., 2002. Qualitative Spatio-Temporal Reasoning with RCC-8 and Allen's Interval Calculus: Computational Complexity. Proc. 15th ECAI02, pp. 312–316*

## *Description of parcel, by relationships to other objects*

### Serialization of Abox ontology in OWL language (Turtle syntax)

```
@prefix : <http://wogis2.igig.up.wroc.pl/abox/sdss/toporel_abox#> .
@prefix plankb: <http://wogis2.igig.up.wroc.pl/tbox/sdss/sdss_plankb_tbox#> .
@prefix spatial: <http://geovocab.org/spatial#> .
@prefix geometry: <http://geovocab.org/geometry#> .

:PL.320604_5.dzialka.acb49b12-db06-4200-92ad-261c72c5e62b.2012-11-08T09-30-29.632451_01 rdf:type plankb:Parcel ,
                owl:NamedIndividual ;
        rdfs:label "32"^^xsd:string ;
        plankb:areaMeasureInHectars "0.050287890625"^^xsd:double ;
        plankb:areaMeasureInSquareMeters "502.87890625"^^xsd:double ;
        rdfs:comment "Działka geodezyjna nr 32"^^xsd:string ;

        spatial:PPi :PL.320604_5.budynek.50f48357-9bd0-4932-a6b4-3fb2a900f9f2.2012-11-08T09-30-29.632451_01 ,
                :PL.320604_5.budynek.603be7e9-cd3c-4a2d-a667-535ea023ea13.2012-11-08T09-30-29.632451_01 ,
                :PL.320604_5.budynek.6e241977-659c-4c0e-9a42-fbd35a3d8bb6.2012-11-08T09-30-29.632451_01 ,
                :PL.320604_5.budynek.9c4fc787-1ef5-4363-90ee-17d6a947ed7c.2012-11-08T09-30-29.632451_01 ,
                :PL.320604_5.budynek.d8a9721e-ba2b-47c0-b9b2-6d2da77253b3.2012-11-08T09-30-29.632451_01 ;

        spatial:EC :PL.320604_5.dzialka.14d39036-86b5-4a5f-8df8-8ab7bec8eb7f.2012-11-08T09-30-29.632451_01 ,
                :PL.320604_5.dzialka.326ee9fd-a43b-4925-9a1d-ace794d2a200.2012-11-08T09-30-29.632451_01 ,
                :PL.320604_5.dzialka.8dd56195-011f-41cf-a6d4-21d1746380bc.2012-11-08T09-30-29.632451_01 ,
                :PL.320604_5.dzialka.ad384c06-00cd-4f5c-adff-3312480e10a7.2012-11-08T09-30-29.632451_01 ,
                :PL.320604_5.dzialka.add425d0-6062-4100-b3c9-c74362a41ad7.2012-11-08T09-30-29.632451_01 ;

        spatial:O :PL.320604_5.uzytek.be19a818-3aba-4e2e-9826-c703aa503f63.2012-11-08T09-30-29.632451_01 ;

        plankb:relationToSpatPlanArea plankb:objectNotCoveredBySpatialPlan .
```

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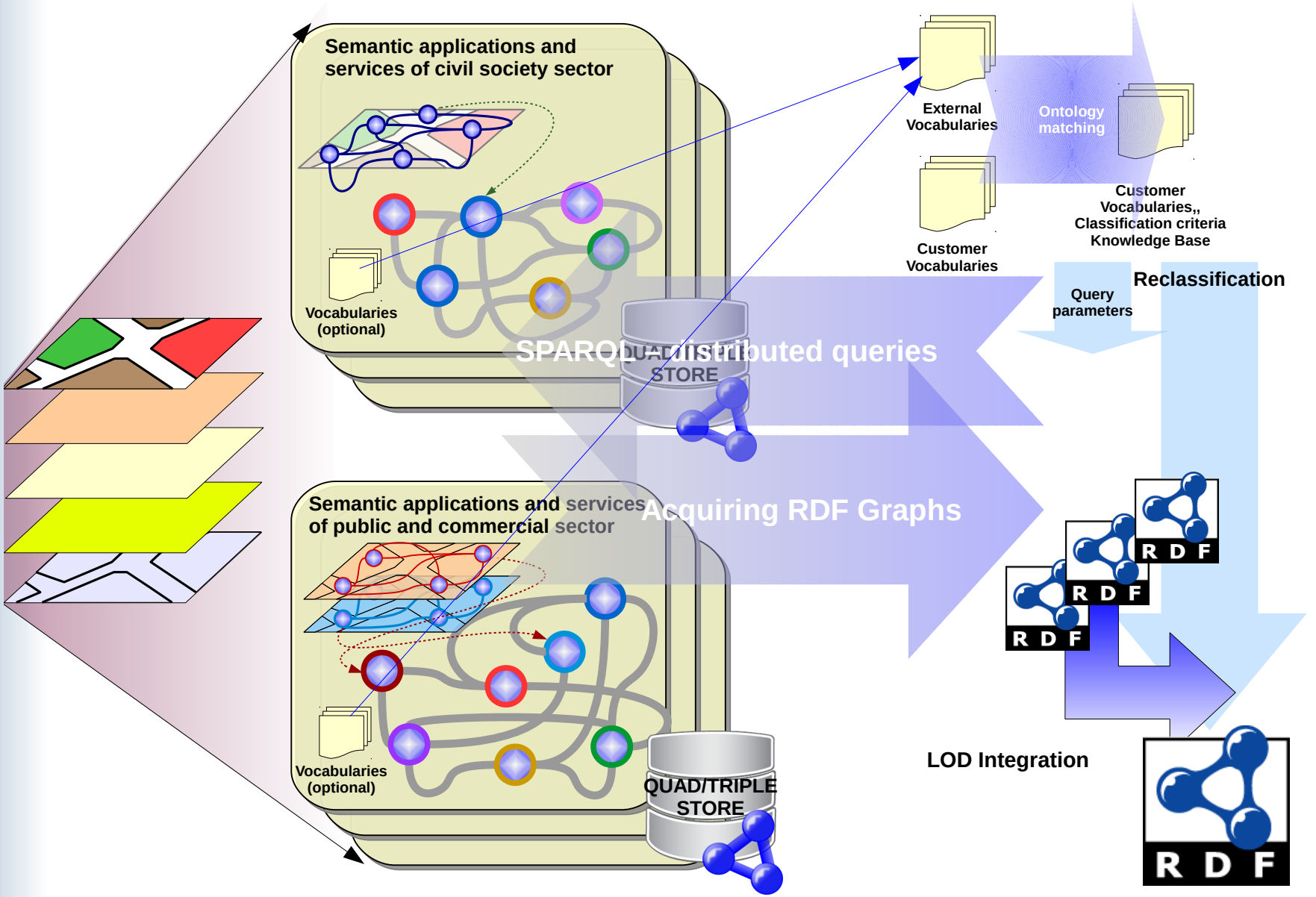



Jaromar Łukowicz, Adam Iwaniak

## *Representation of time-aware semantic spatial data in LOD*

### Temporal representation in LOD – possible techniques

- annotated RDF – aRDF (annotation of each triple in textual form or using some vocabulary in form of code list),
- quad-store structures (standardized in RDF 1.1 spec.)
  - N-Quads – extension to N-Triples notation (triple with context),
  - named graphs: triple(s) is (are) nested within graph, which is distinguished by unique name – TriG extension to RDF Turtle or TriX RDF/XML notation
  - JSON-LD – new RDF serialization in JSON notation.
- temporal graphs*,
- temporal information inside RDF ABox structure, as additional triples describing entities (things) using dedicated predicates defined in vocabulary (TBox).

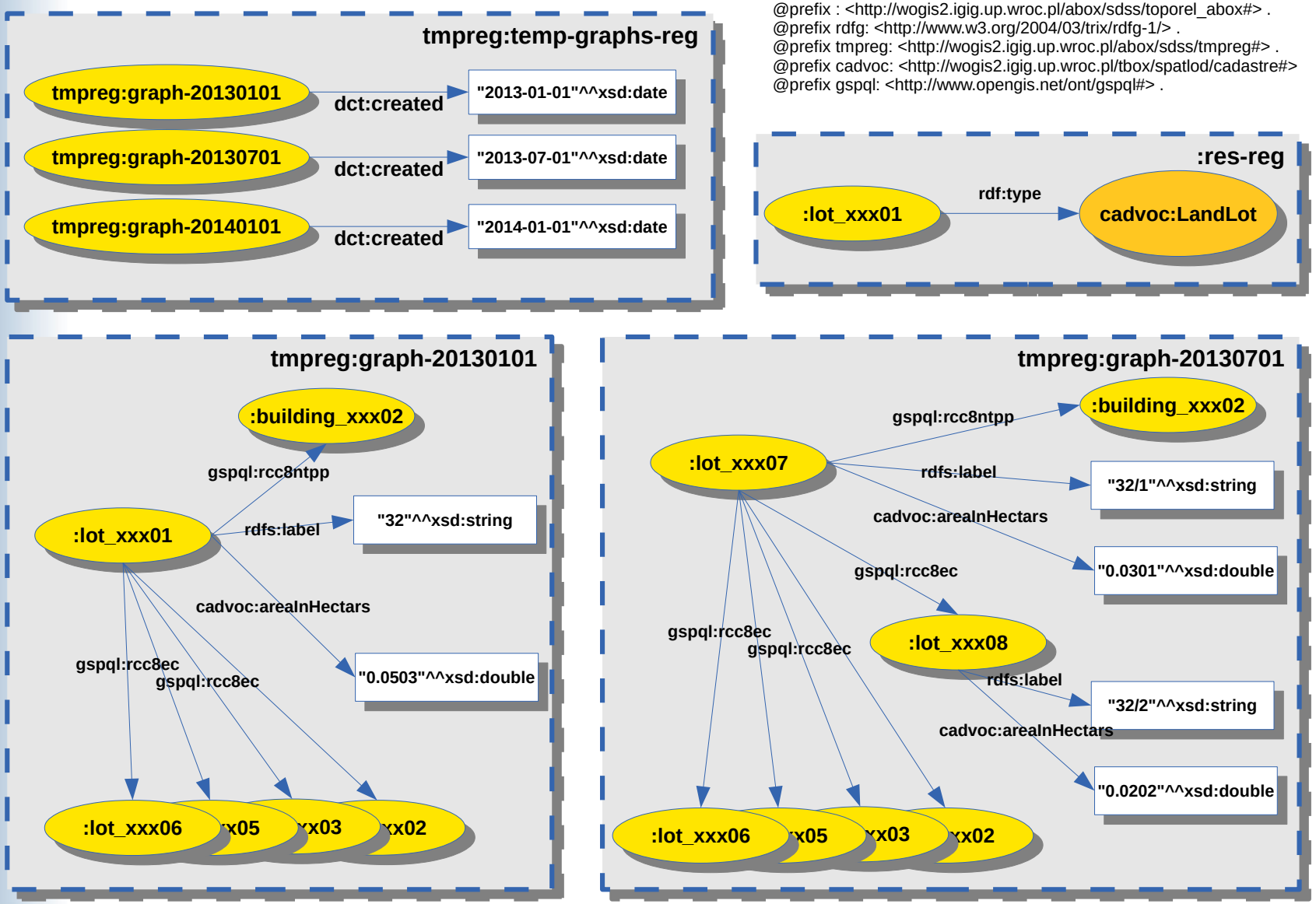
*Gutierrez, C., Hurtado, C.A., Vaisman, A., 2007. Introducing Time into RDF. IEEE Transactions on Knowledge and Data Engineering, Vol. 19, No. 2, p. 207

# Representation of temporal issues in LOD

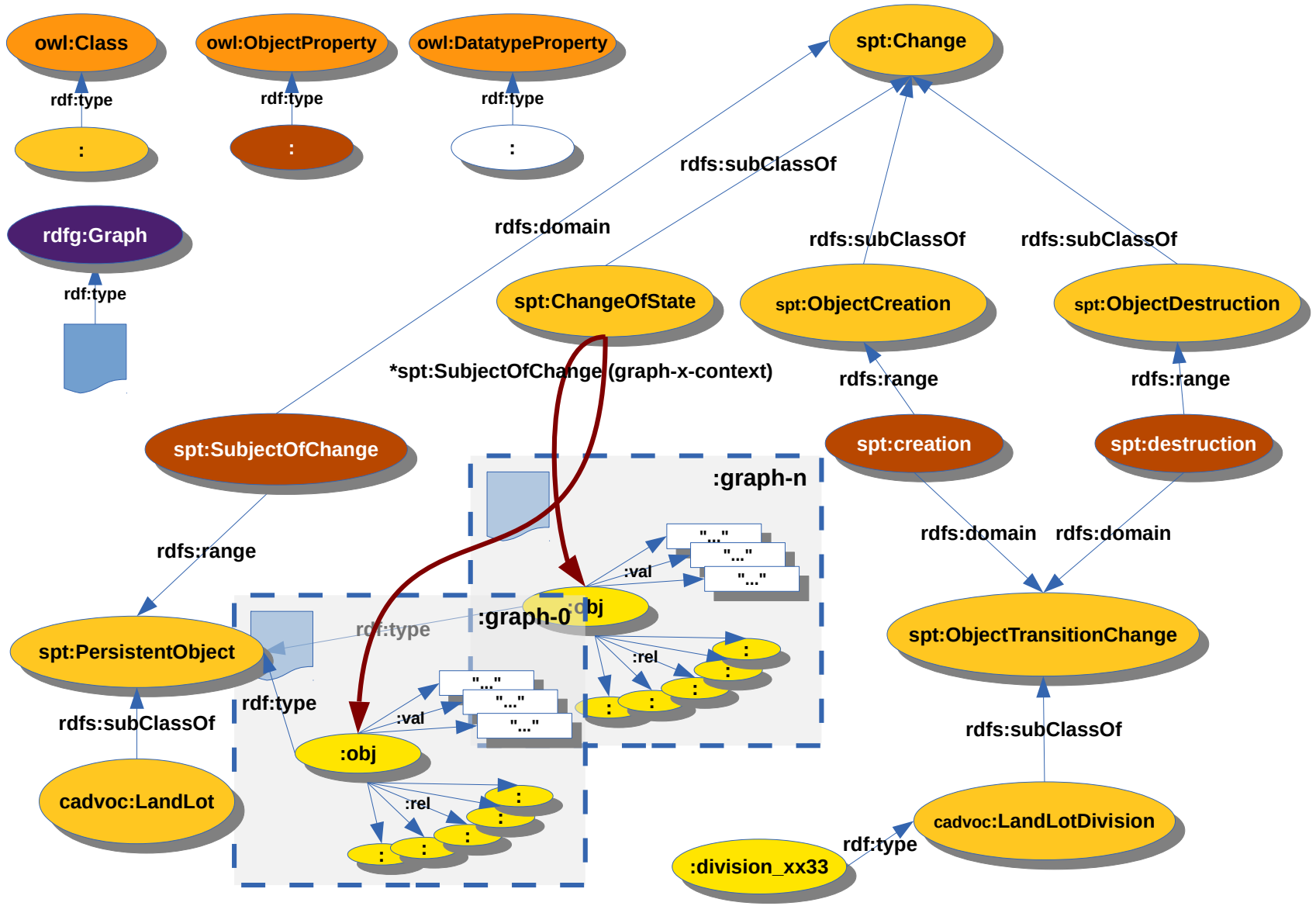
```
@prefix : <http://wogis2.igig.up.wroc.pl/abox/spatlod/toporel_abox#> .
# ...
@prefix rdfg: <http://www.w3.org/2004/03/trix/rdfg-1/> .
@prefix tmpreg: <http://wogis2.igig.up.wroc.pl/abox/spatlod/tmpreg#> .
@prefix cadvoc: <http://wogis2.igig.up.wroc.pl/tbox/spatlod/cadastre#>
@prefix gspql: <http://www.opengis.net/ont/gspql#> .


:res-reg {
   :PL.320604_5.dzialka.acb49b12-db06-4200-92ad-261c72c5e62b rdf:type cadvoc:LandLot.
   :PL.320604_5.dzialka.14d39036-86b5-4a5f-8df8-8ab7bec8eb7f rdf:type cadvoc:LandLot.
   :PL.320604_5.dzialka.326ee9fd-a43b-4925-9a1d-ace794d2a200 rdf:type cadvoc:LandLot.
}
tmpreg:graph-20130101 {
   :PL.320604_5.dzialka.acb49b12-db06-4200-92ad-261c72c5e62b rdfs:label "32"^^xsd:string ;
            cadvoc:areaInHectars "0.050287890625"^^xsd:double;
            cadvoc:created "2012-05-28"^^xsd:date.
   :PL.320604_5.dzialka.14d39036-86b5-4a5f-8df8-8ab7bec8eb7f rdfs:label "33"^^xsd:string ;
            cadvoc:areaInHectars "0.0678658877"^^xsd:double;
            cadvoc:created "1984-05-28"^^xsd:date.
   :PL.320604_5.dzialka.326ee9fd-a43b-4925-9a1d-ace794d2a200 rdfs:label "34"^^xsd:string ;
            cadvoc:areaInHectars "0.0708124454"^^xsd:double.
}
tmpreg:graph-20130701 {
   :PL.320604_5.dzialka.acb49b12-db06-4200-92ad-261c72c5e62b rdfs:label "32/1"^^xsd:string ;
            cadvoc:areaInHectars "0.043887890625"^^xsd:double;
            cadvoc:created "2012-05-28"^^xsd:date;
            cadvoc:divided "2013-05-03"^^xsd:date.
   #...
}
tmpreg:graph-20140101 {
   # ...
}
tmpreg:temp-graphs-reg {
    tmpreg:graph-20130101 dct:created "2013-01-01"^^xsd:date.
    tmpreg:graph-20130701 dct:created "2013-07-01"^^xsd:date.
    tmpreg:graph-20140101 dct:created "2014-01-01"^^xsd:date.
}
```

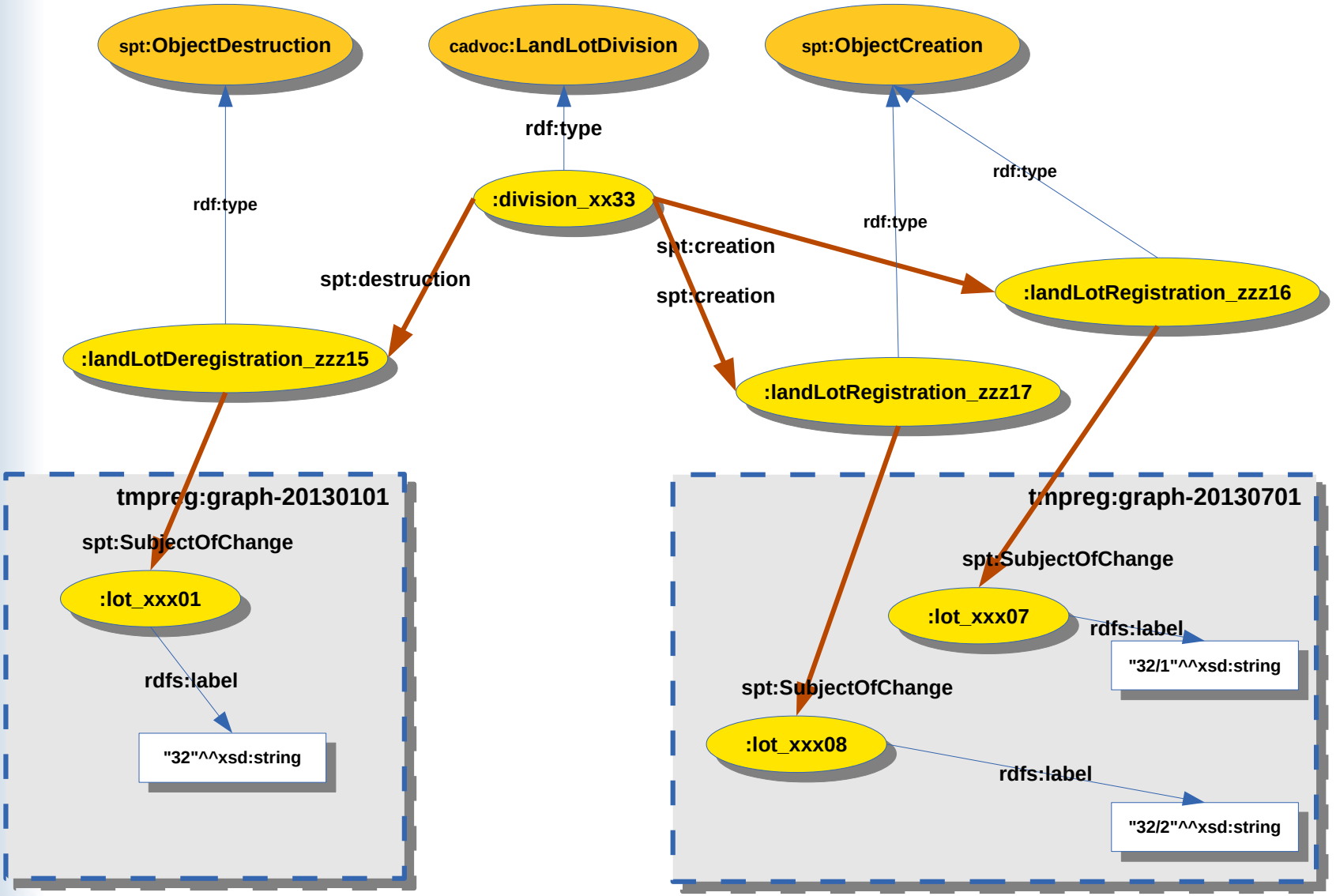
# Representation of temporal issues in LOD



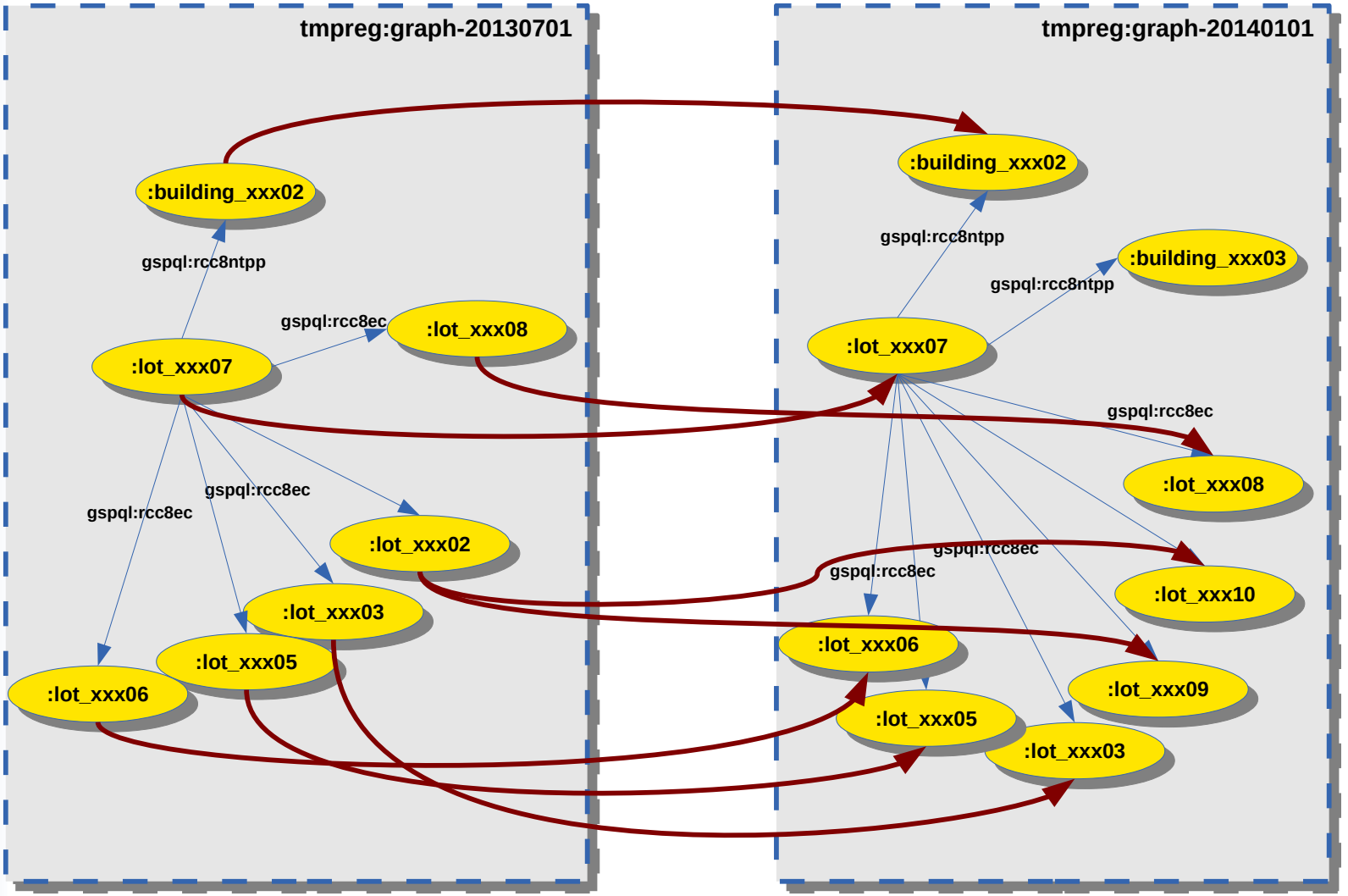
## *Representation of temporal issues in LOD*



## Representation of temporal issues in LOD

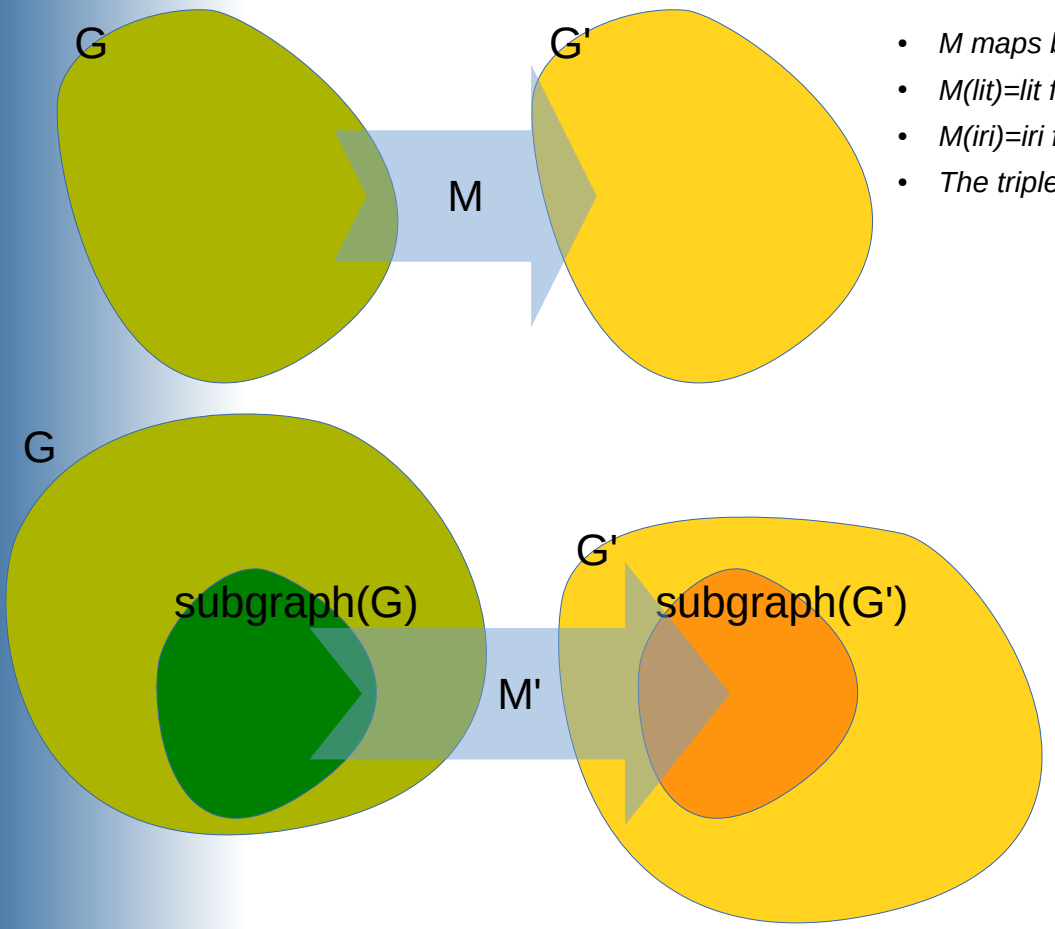


# Detection of changes in LOD – provenance (genidentity*)



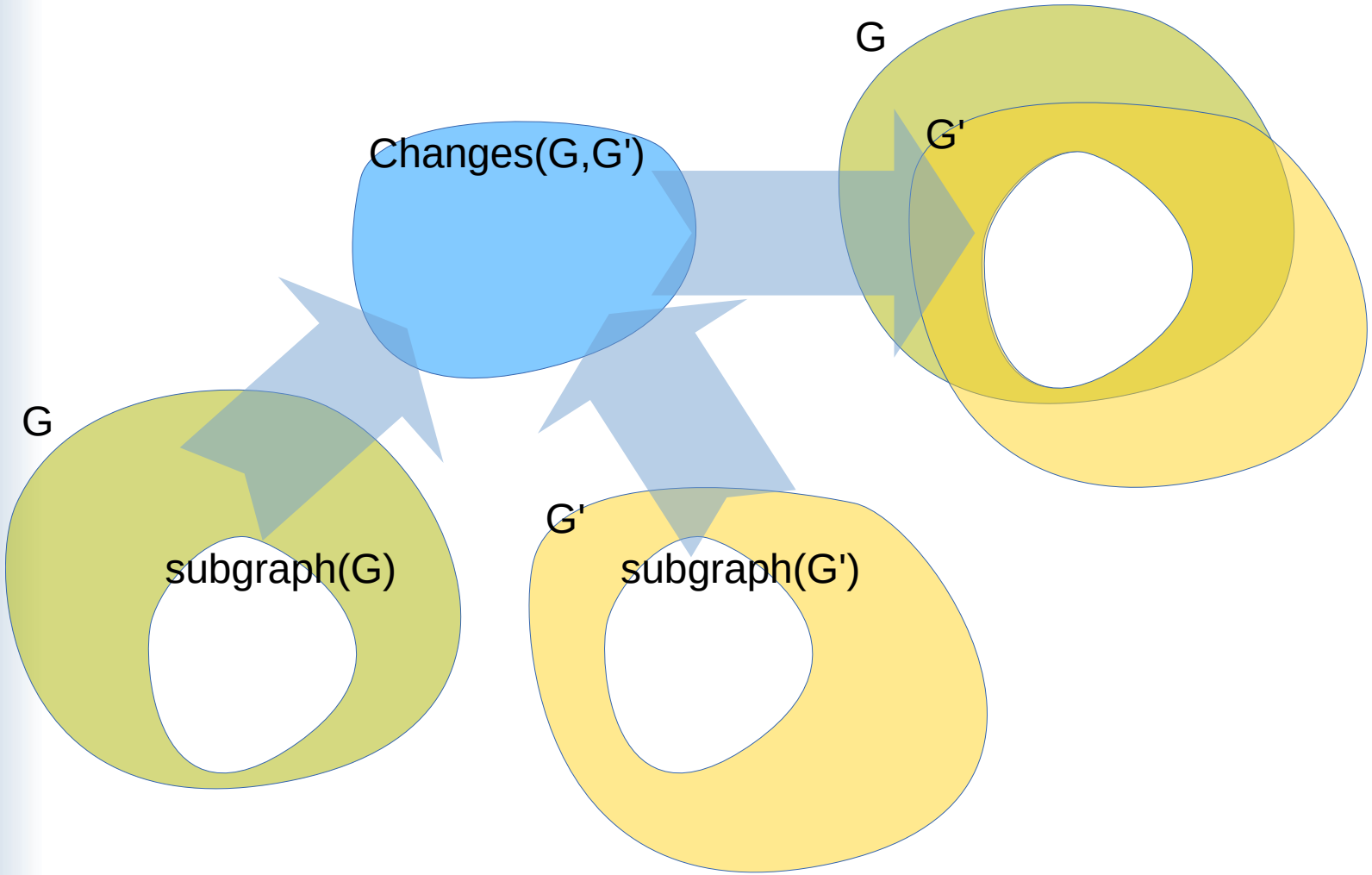

** Concept of genidentity was introduced by Kurt Lewin. Genidentity is an existential relationship underlying the genesis of an object from one moment to the next.*

## *Detection of changes in LOD*




- *M maps blank nodes to blank nodes.*
- *M(lit)=lit for all RDF literals lit which are nodes of G.*
- *M(iri)=iri for all IRIs iri which are nodes of G.*
- *The triple ( s, p, o ) is in G if and only if the triple ( M(s), p, M(o) ) is in G'*

## *Detection of changes in LOD*



## *Distinction of ontologies due to level of abstraction*

### Formal ontologies and material ontologies

- Husserl (Logical Investigations 1913/21) made distinction between:
  - **Formal ontology** – as theory on supreme, domain neutral level.
    - formal ontology deals with categories and relations, that are common for **all domains** and which applicable to reality in each perspective. Such categories and relations are: *object, relation, group, quantity, part, identical to* and so on.
  - **Material ontologies** (also known as regional) – that are ontologies of particular domains. Here they will be called as domain ontologies.

Grenon, P, Smith, B. 2004. SNAP and SPAN: Towards Dynamic Spatial Ontology. Spat.Cog.Comp., Vol. 4, pp. 69-104.

## *Upper formal ontologies*

**List of selected upper ontologies (foundational ontologies)**

- **BFO** - Basic Formal Ontology,
- **DOLCE** - Descriptive Ontology for Linguistic and Cognitive Engineering,
- **GFO** - General Formal Ontology (medycyna, biologia)
- **OCHRE** - Object-Centered High-level REference ontology
- **SUMO** - Suggested Upper Merged Ontology
- ...

*Grenon, P, Smith, B. 2004. SNAP and SPAN: Towards Dynamic Spatial Ontology. Spat.Cog.Comp., Vol. 4, pp. 69-104*
*Grenon, P, 2003. BFO in a Nutshell: A Bi-categorial Axiomatization of BFO and Comparison with DOLCE, IFOMIS REPORTS*

## *Spatio-temporal model in formal ontologies*

**Main distinction of entities, due to their behavior in time**

- Objects persistent in time: **endurants** or continuants;
- Objects “happening”, “flowing”, “occurring” in time: **perdurants** or occurents.

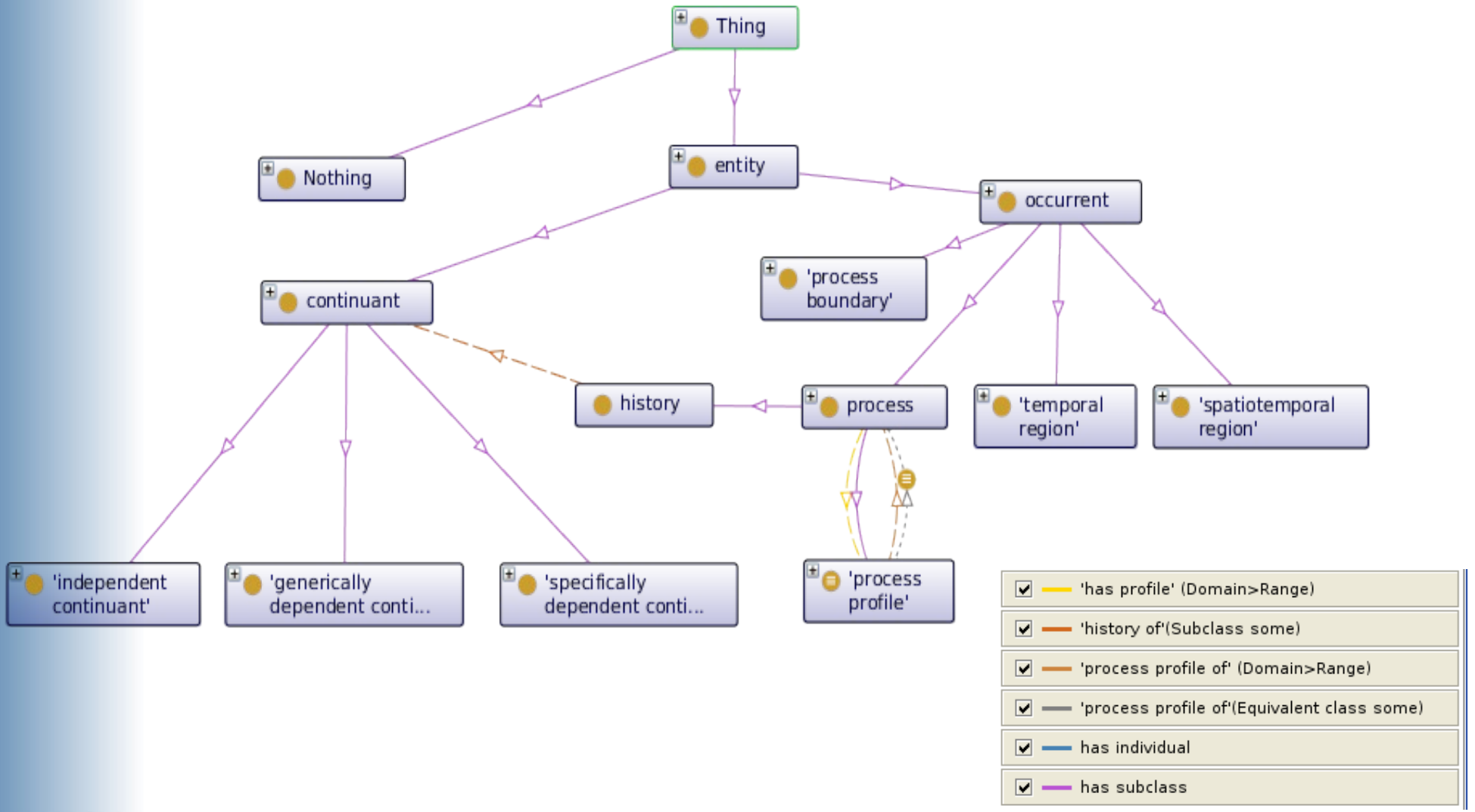
**Endurants / continuants**:

- physical objects (building, road, parking, tree, lake, river !!!);
- abstract objects, which are persistent (parcel, plan zone, land use contour).

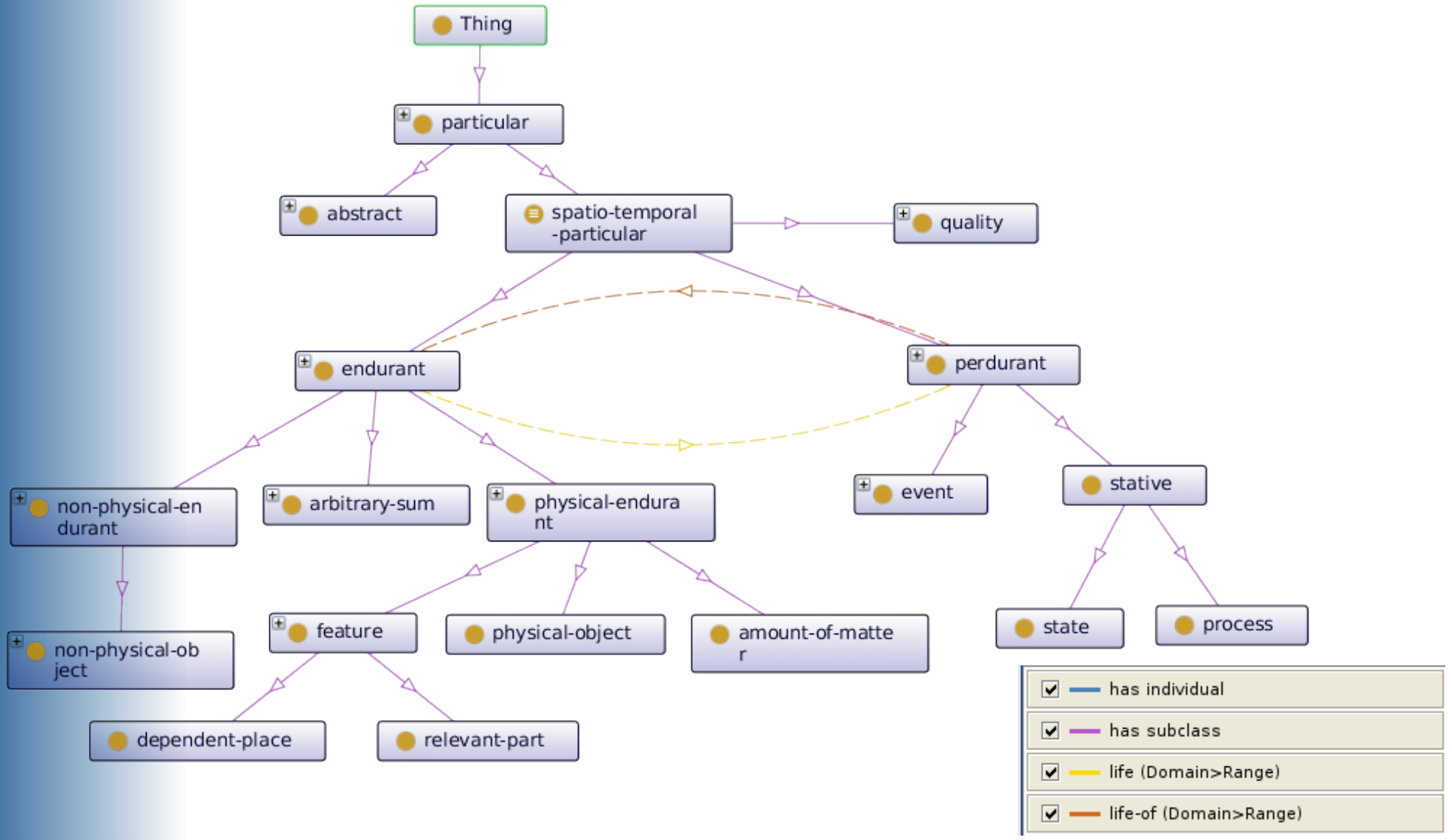
**Perdurants / occurents**:

- events – parcel division (it is end of object and creation of new objects)
- processes - water outflow from lake, water flow, decrease of population, deforestration.

## *Spatio-temporal model in formal ontologies (BFO)*



## *Spatio-temporal model in formal ontologies (DOLCE)*



## *Spatio-temporal nature of phenomena*

**Nature of entity – set of qualities (properties) describing object**

Due to Kant, phenomenon is an object (occurence or fact) as it is perceived by the senses.

**As a phenomenon**, we can consider e.g. occurent, continuant in some circumstances or continuant with observed state in given moment.

As opposed to a phenomenon, noumenon is the "thing-in-itself" – the real entity (being of existence) which we try to describe, using recognizable properties.

**Nature of phenomena**, as a set of properties in our model:

- could determine object's identity in a given moment,
- could determine type of entity in a given moment,
- describes the state of continuant in a given moment,
- describes the profile of occurent;

## *Behavior of continuants due to their essence*

### Behavior of continuants varies due to their substance and mereological structure

In BFO, continuants are distinguished, by combination of two oppositions:

- dissective – non dissective objects;
- cumulative – non cumulative objects.

Entities, which in some resolution (level of granularity), we can consider as consisted of homogeneous substance and and their shape does not determine their type, often are both: dissective and cumulative:

- cadastral parcels,
- land use units, planning zones,

Entities, which, in some resolution (level of granularity), we can consider as consisted of heterogeneous substrates (have complex mereological structure) or their shape determines their type often, are both non dissective and non cumulative:

- specimen (organisms) of fauna and flora,
- human persons.

Buildings or building structures classification depends on their design, construction or functional structure and last but not the least, the level of granularity, in which we consider that entities. Great modular dwelling building could be dissective, but stadium, bridge couldn't. The similar problem: land lots, administrative units / areas.

## *Nature of occurents due to their period*

**Events and processes**

- Events causing discrete changes.
- Processes causing continuous.

## *Spatio-temporal model in BFO – temporal succession of objects*

**Genidentity.** Important structure describing life of objects is **genidentity.**

- To mutual refer object in different snapshots is important to show the dependencies of preceding and succession of objects.
- *Genidentity provides information about the trans-ontological filiations of objects**.
- Its role is similar to that used in traditional GIS determination of object predecessors and successors.

Example: history of states in medieval ages. Feudal ruler divided his state between sons. Next example: division of parcels.

*Grenon, P, Smith, B. 2004. SNAP and SPAN: Towards Dynamic Spatial Ontology. Spat.Cog.Comp., Vol. 4, pp. 69-104*

*Concept of genidentity was introduced by Kurt Lewin. Genidentity is an existential relationship underlying the genesis of an object from one moment to the next.*

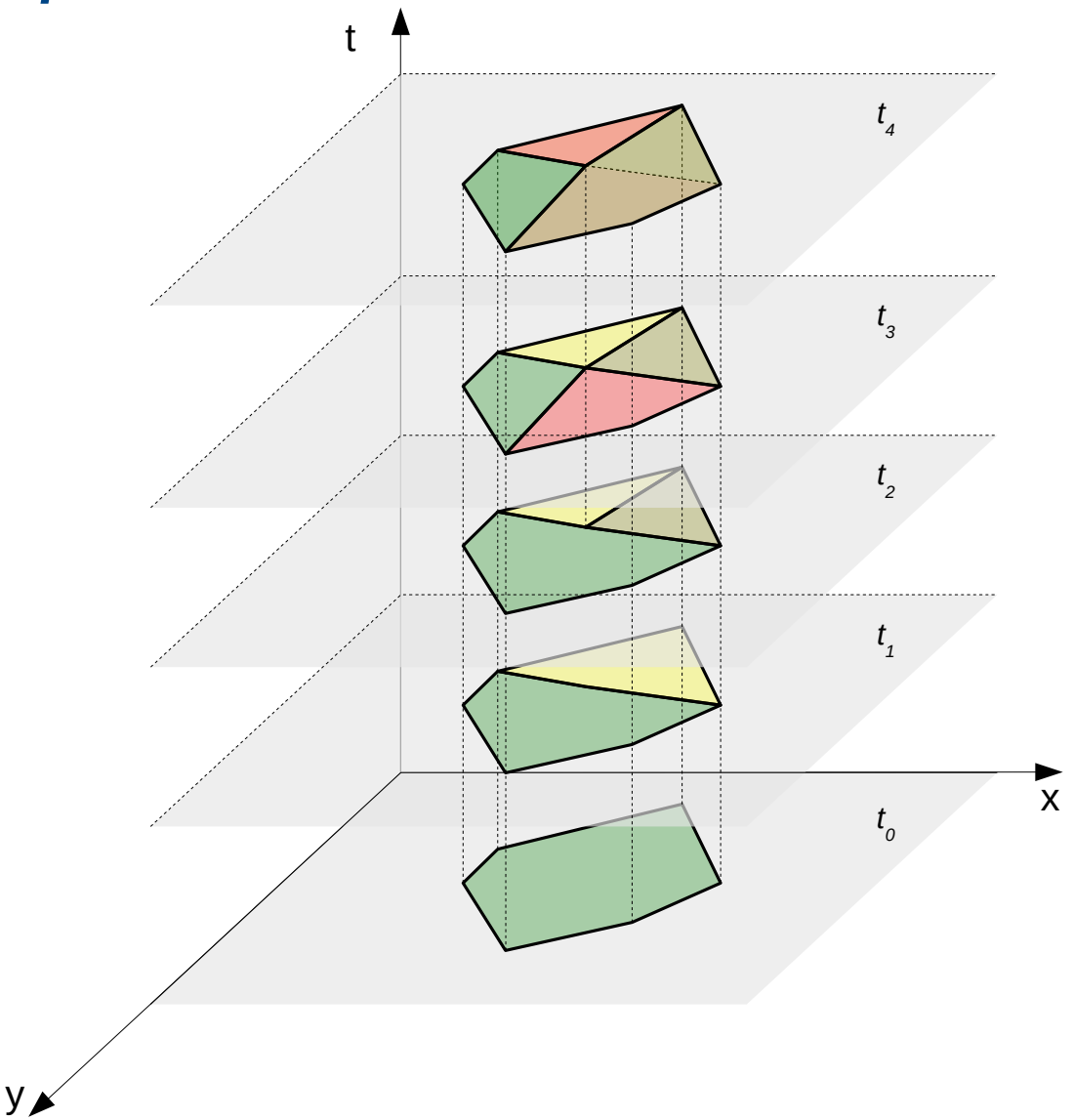
## *Spatio-temporal model in BFO*

### Changes and their impact on entities

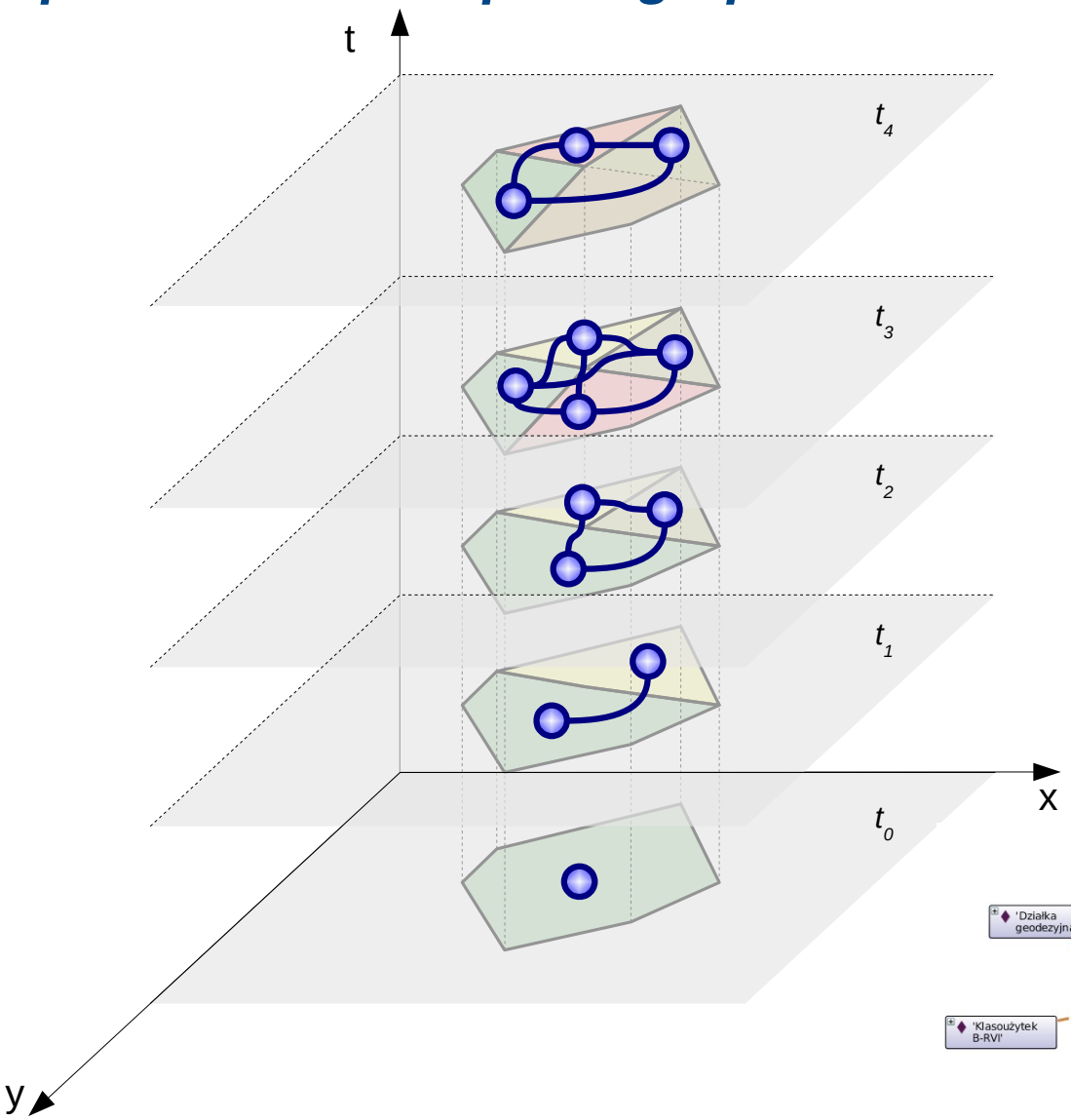
BFO defines 3 groups of changes of continuants, affecting their type and consequently their state or existence:

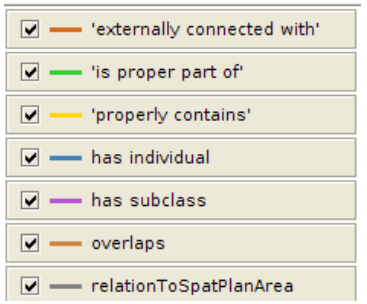
1. Qualitative Change
2. Substantial Change
3. Spatial and Locational Change

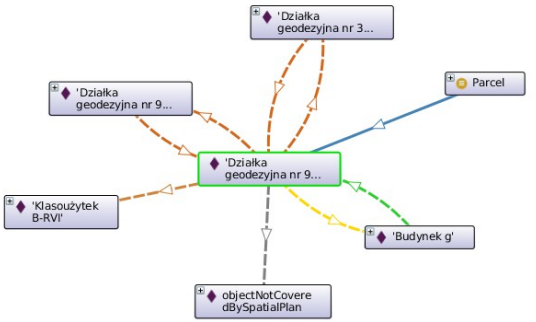
## Spatio-temporal model in SDI



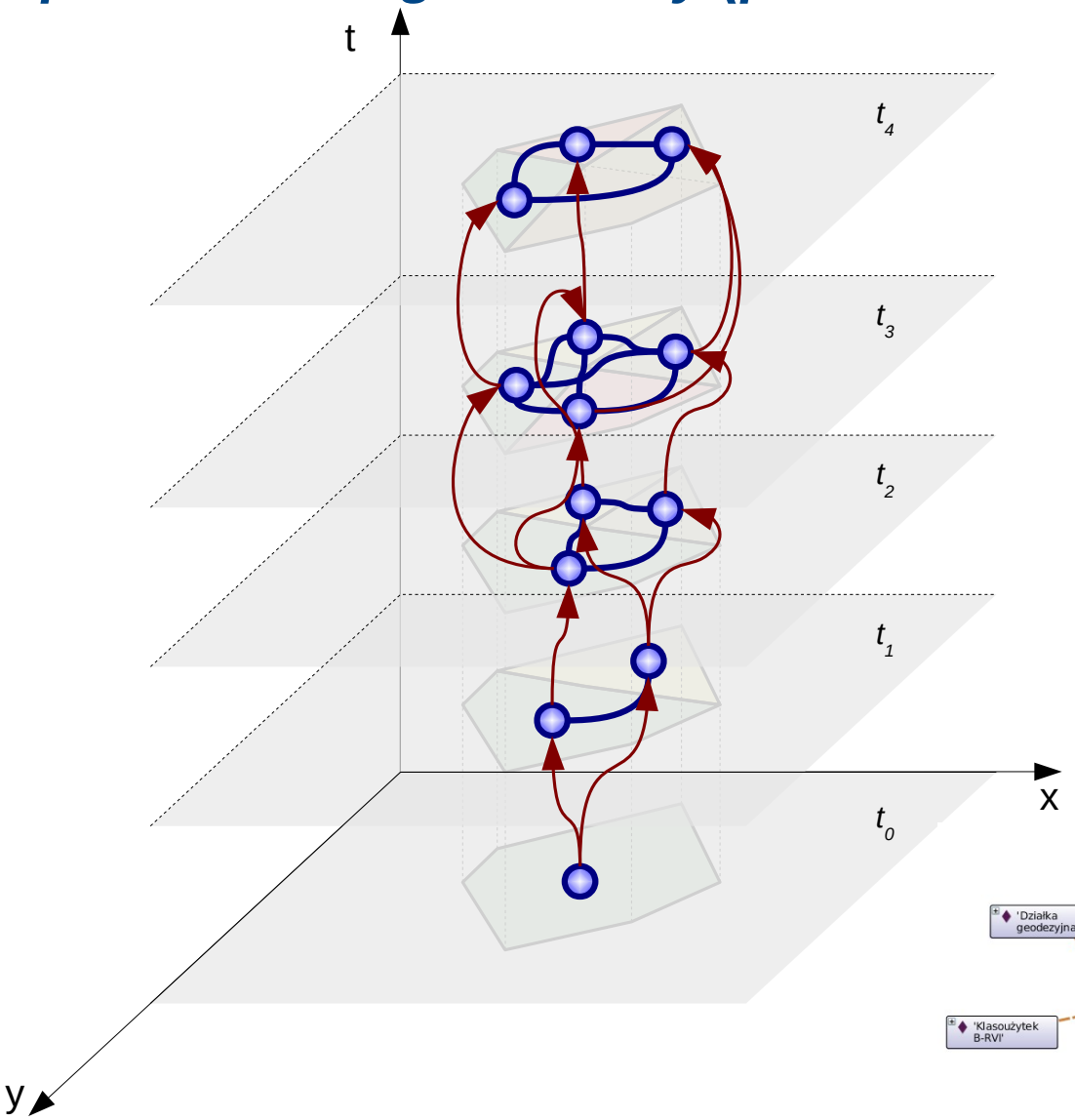
## Spatio-temporal model temporal graphs



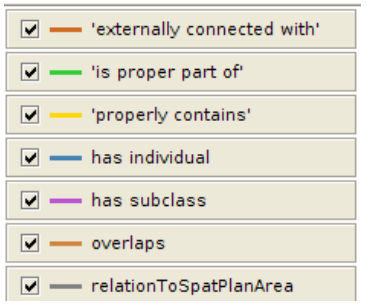



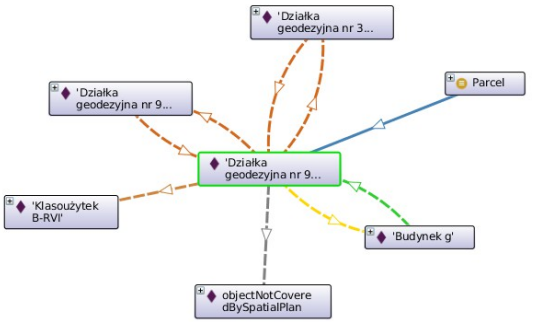



## *Spatio-temporal model: genidentity (provenance or pedigree)*

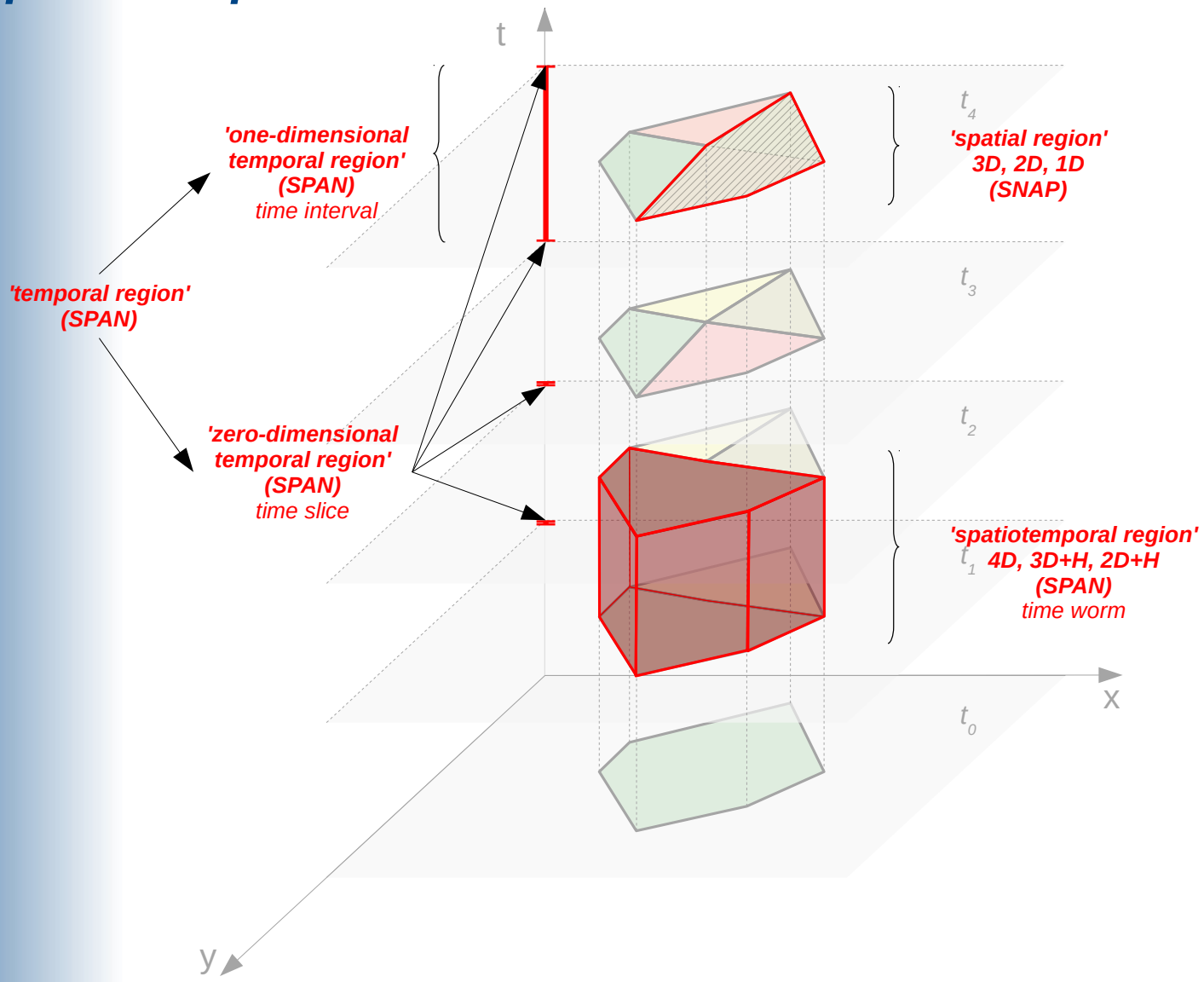



Genidentity

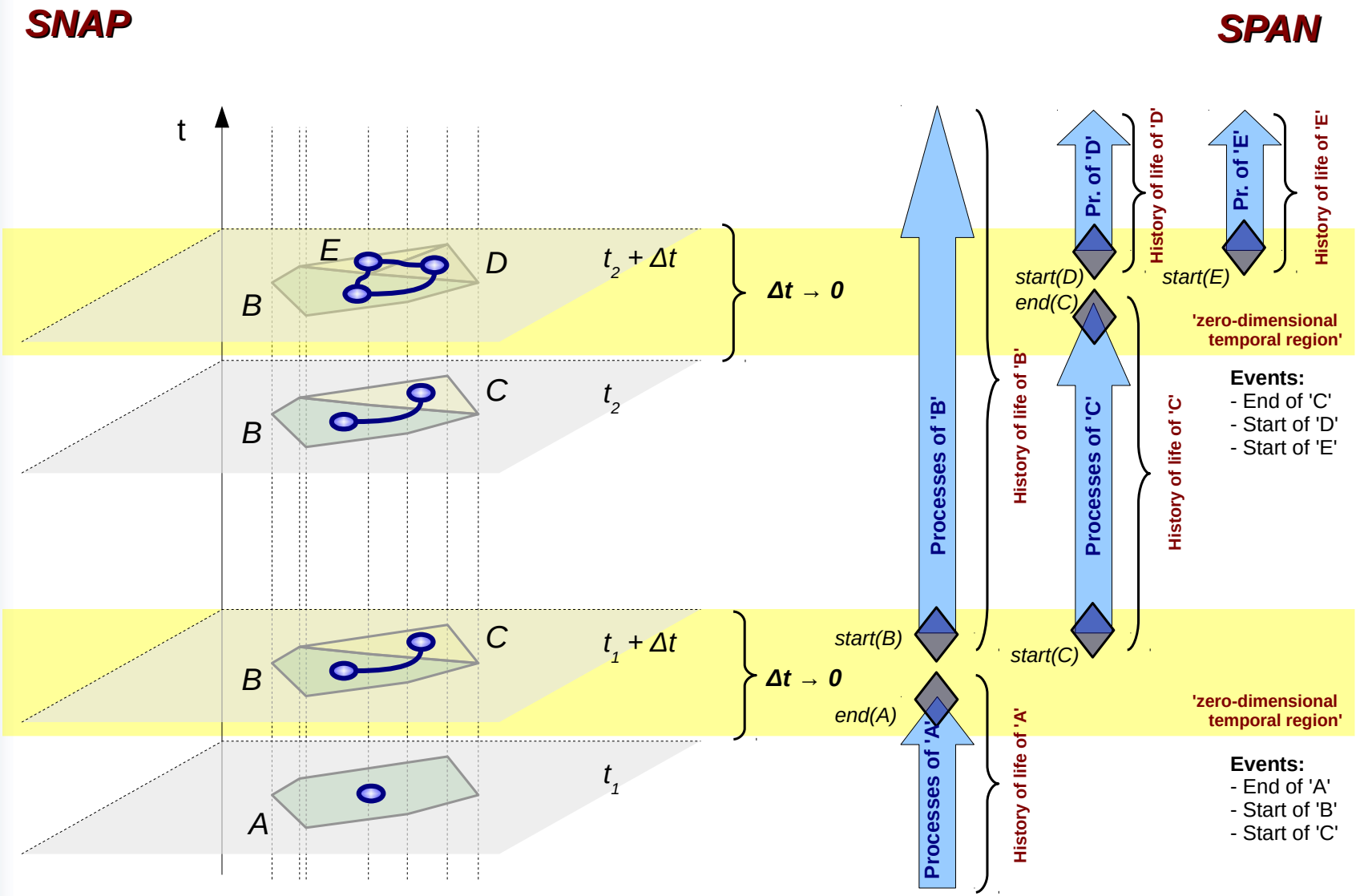


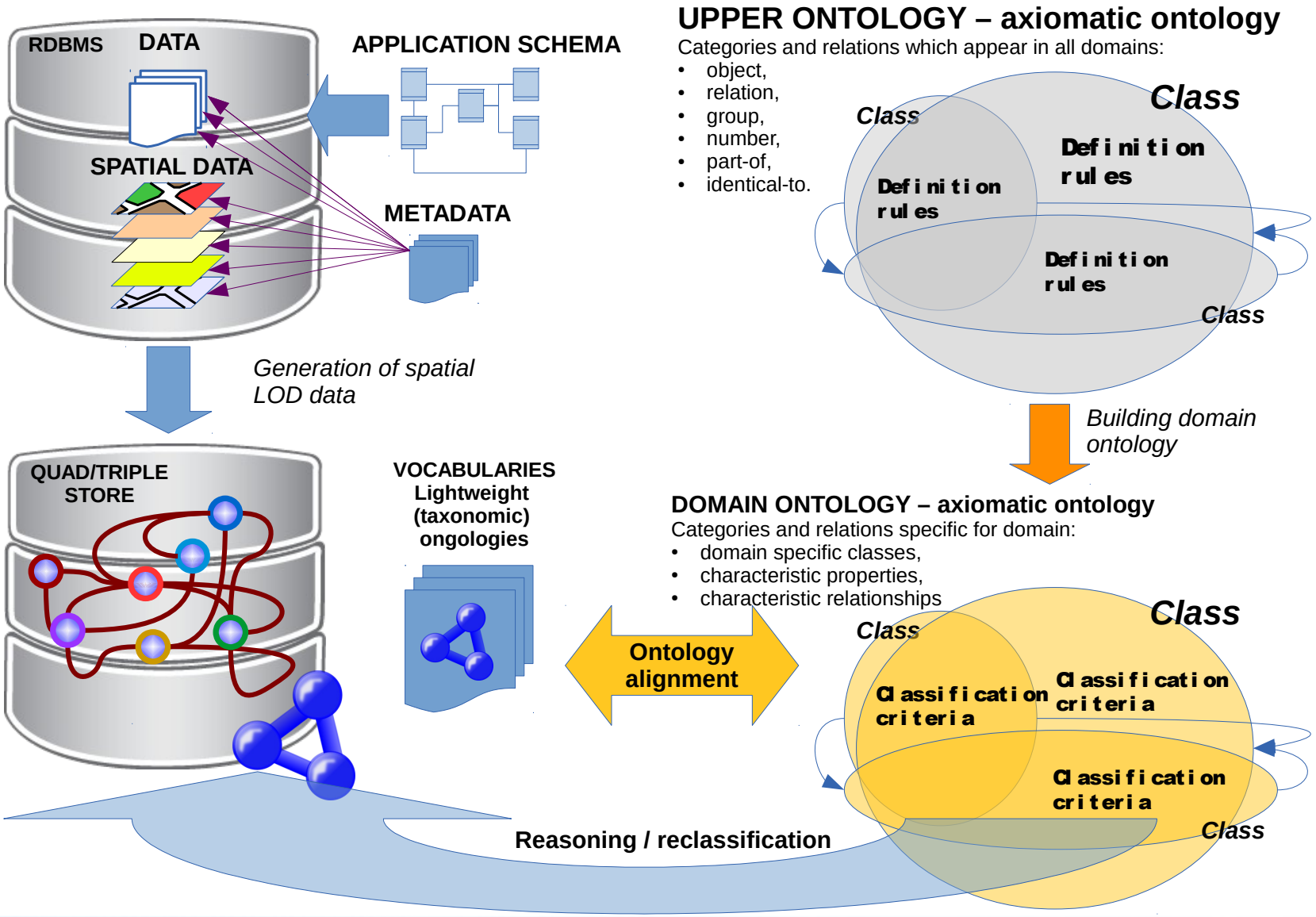
# Spatio-temporal model in BFO – SPAN and SPAN-SPAN



# Spatio-temporal model in BFO – SNAP-SPAN and SPAN-SNAP



# *Involving constructs of upper ontology into spatial LOD*



# *Injection formal spatio-temporal structures into LOD resources (building axiomatic domain ontology)*

## Extending class hierarchy of Formal Ontology by domain objects

**Endurants / Continuants**

- land lots
- land use units
- buildings
- spatial plan zones

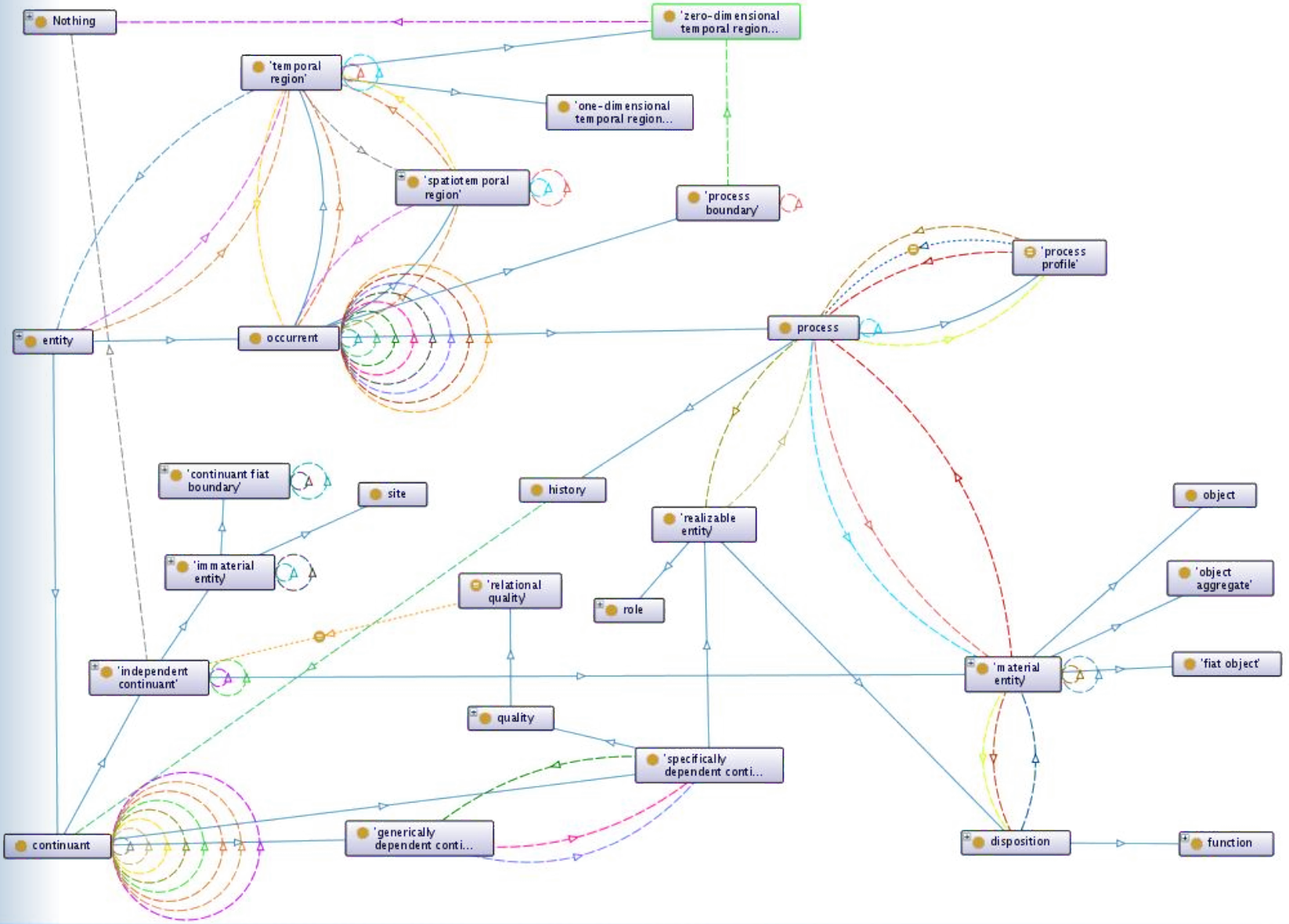
**Perdurants / Occurents**

- Discrete – events
  - division of land lot,
  - adoption of spatial planning resolution,
  - change of formal land use state,
  - realization of building (it depends of time resolution – temporal granularity)
- Continuous – processes
  - changes in land cover (deforestation),
  - expansion of urban areas (suburbanization, urban sprawl),

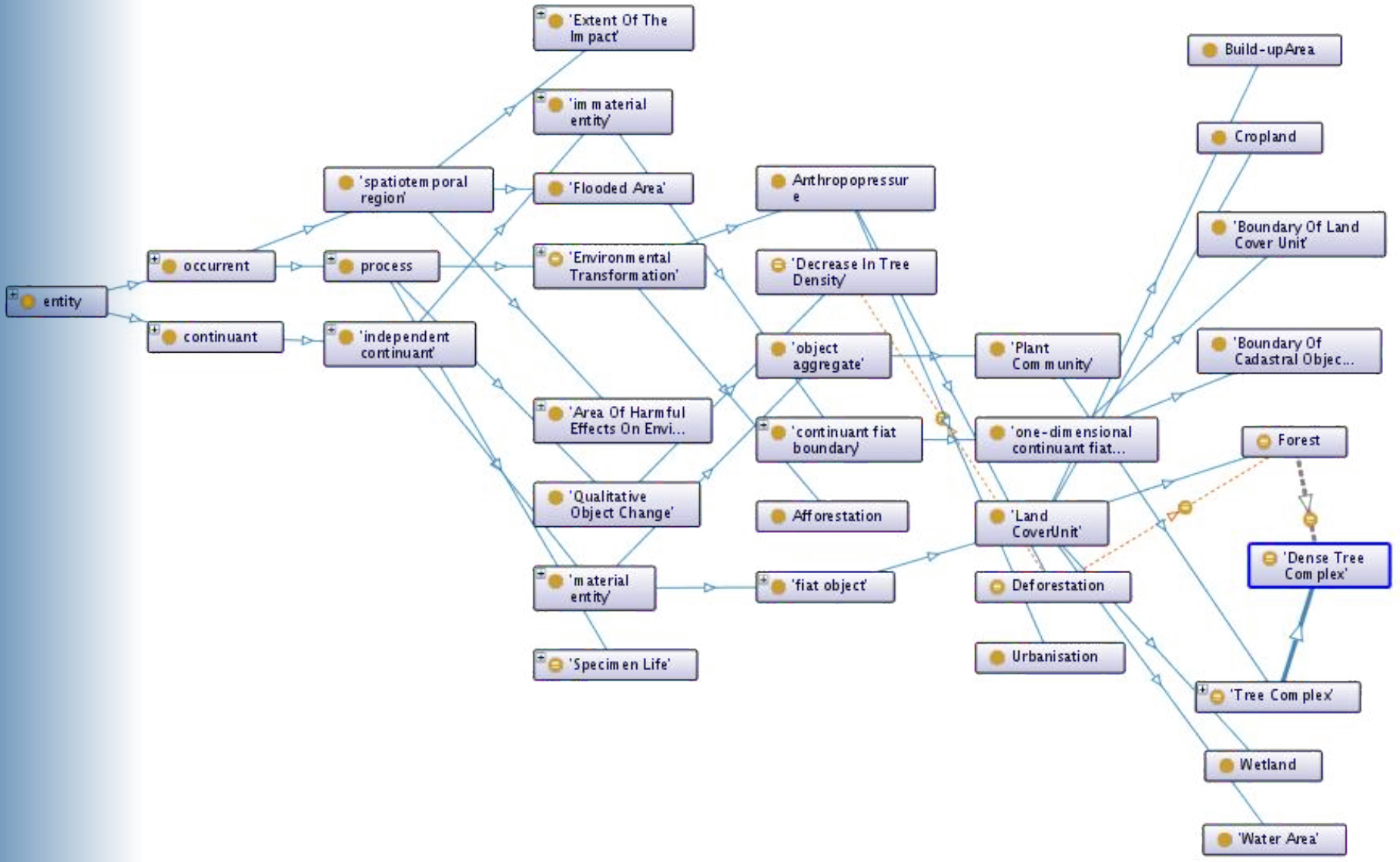
# Discovering Spatio-temporal Nature of Phenomena from Linked Open Data Generated from SDI Spatial Resources, Using Formal Ontologies

woGIS semantics

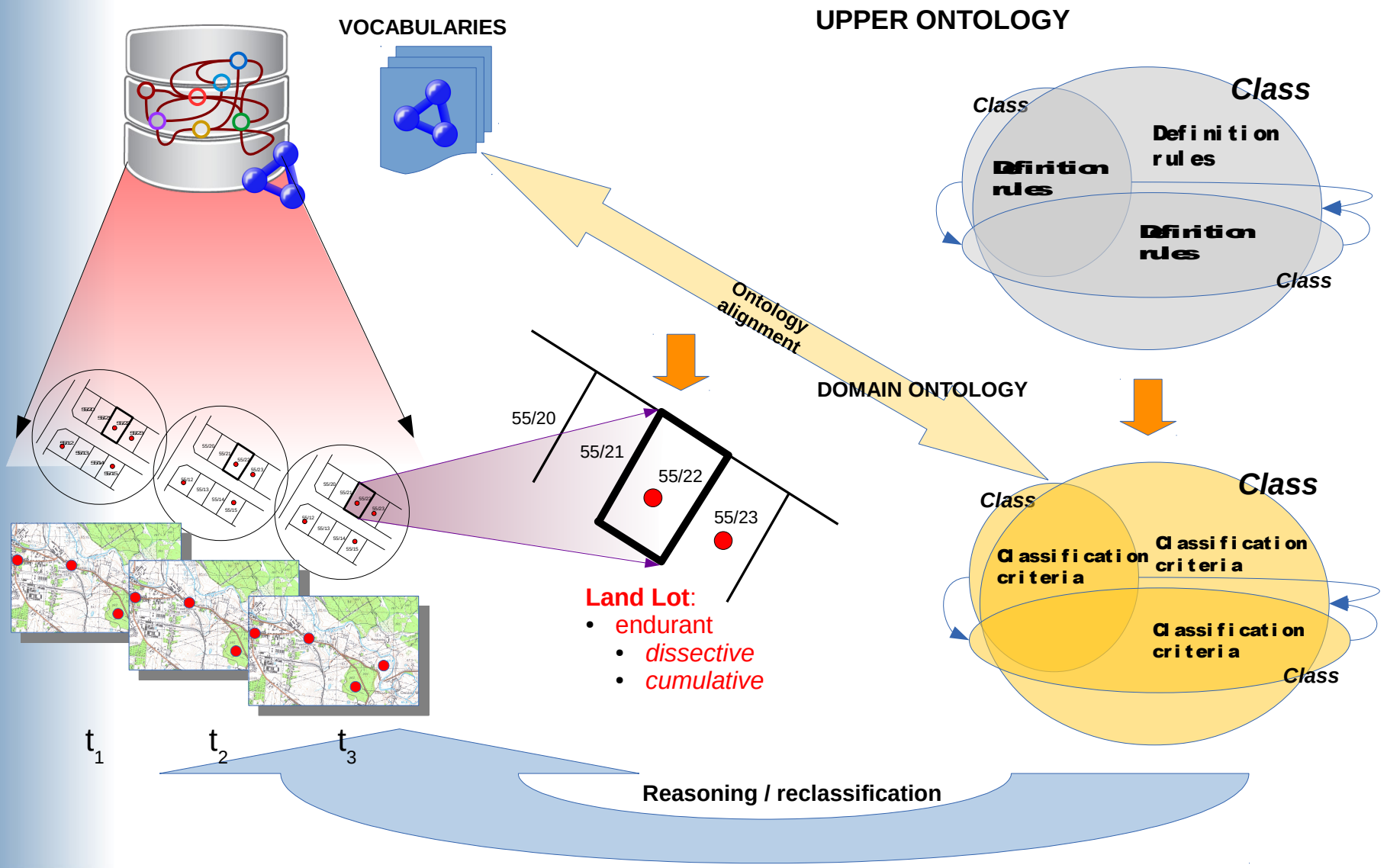
## *Spatio-temporal model in BFO*



# *Extending spatio-temporal model from BFO by domain objects*



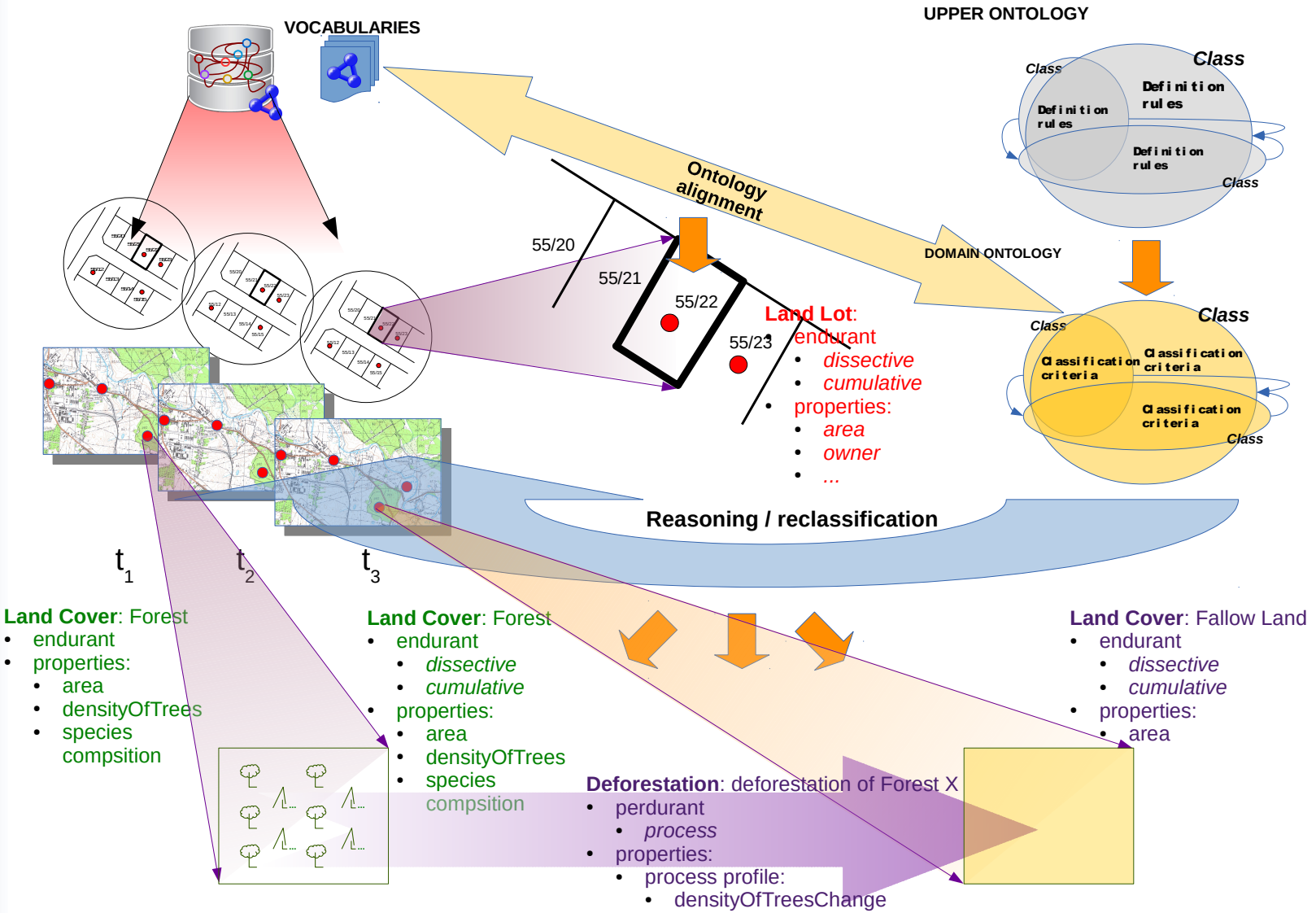
# Mapping domain ontology to LOD vocabulary



# Discovering Spatio-temporal Nature of Phenomena from Linked Open Data Generated from SDI Spatial Resources, Using Formal Ontologies

woGIS semantics

## *Discovering spatio-temporal qualities of phenomena by inference*



## *Conclusions*

### Representing dynamic of spatial data in LOD

- Semantic model used in Linked Open Data is flexible and powerful for representation of dynamic spatial data,
- Generation of semantic representation in form of LOD makes it easy to provide information about topological relationships;
- Reflecting dynamics of phenomena in LOD is based upon named graph constructions,
- Temporal description of changes should be implemented in vocabulary – it is important condition, which is needed for acquiring complete information before launch of generating process.

### Extending spatio-temporal model by constructs designed in Formal Ontologies

- Formal ontologies can enrich description of spatio-temporal phenomena,
- They make it possible to describe changes in discrete and continuous form
- The provide constructions for description of impact of perdurants on perdurants state.

## *Future work*

**Possible directions for further research**

- automated reclassification of LOD resources against the formal ontology axiomatic class hierarchy, using reasoning engines,
- automatic discovering cause-effect relationships between events/processes and persistent objects (impact on state of objects).

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# Thank you

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Workshop on Linked Open Data: Activities, Ideas, Practices @ GIForum 2014

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